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BULLETIN

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THE BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

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MARCH 1928

SEDIMENTATION OF THE PICO FORMATION IN THE VENTURA QUADRANGLE, CALIFORNIA[1]

LON D. CARTWRIGHT, JR.[2]
Colorado, Texas

ABSTRACT

The rocks of the Ventura quadrangle are sedimentary strata ranging from Cretaceous to Recent. The pre-Pliocene beds reach a thickness of 22,000 feet, and crop out in parallel, east-west belts. They consist of conglomerates, sandstones, and shales, with minor proportions of dolomite and limestone.

The Pliocene beds comprise the Pico and Saugus formations, which crop out south of the older formations. The Pico formation is divided for convenience of discussion into a lower member 9,300 feet thick and an upper member 3,000 feet thick. The lower Pico consists of heavy conglomerates, sandstones, and clays containing many cross-laminated beds, ripple-marks, and cut-and-fill structures; while the upper Pico consists of monotonously even-bedded, homogeneous, silty clay.

A comparison of the petrology of the older formations and of the Pico indicates that the Pico sediments were derived from these older rocks. During lower Pico time short, swift streams carried detritus from a youthful land-mass located just north of the present outcrop of the formation, to a marine basin. Deposition took place rapidly, and the bottom was recurrently depressed while the adjacent land-mass was recurrently uplifted. By upper Pico time the land-mass had been reduced to maturity or old age, and only the finer debris was carried to the basin.

INTRODUCTION

The Pico formation (lower Pliocene) of the Fernando group (Pliocene) is the producing formation in the Ventura Avenue oil field, one of the largest and most outstanding fields of California to-day, and in many of the fields of the Los Angeles basin. The purpose of this paper is to present the results of an intensive study of the Pico formation

[1]Presented by title before the Association, at the Tulsa meeting, March 26, 1927. Manuscript received by the editor, December 22, 1927.

[2]Geologist, The California Company.

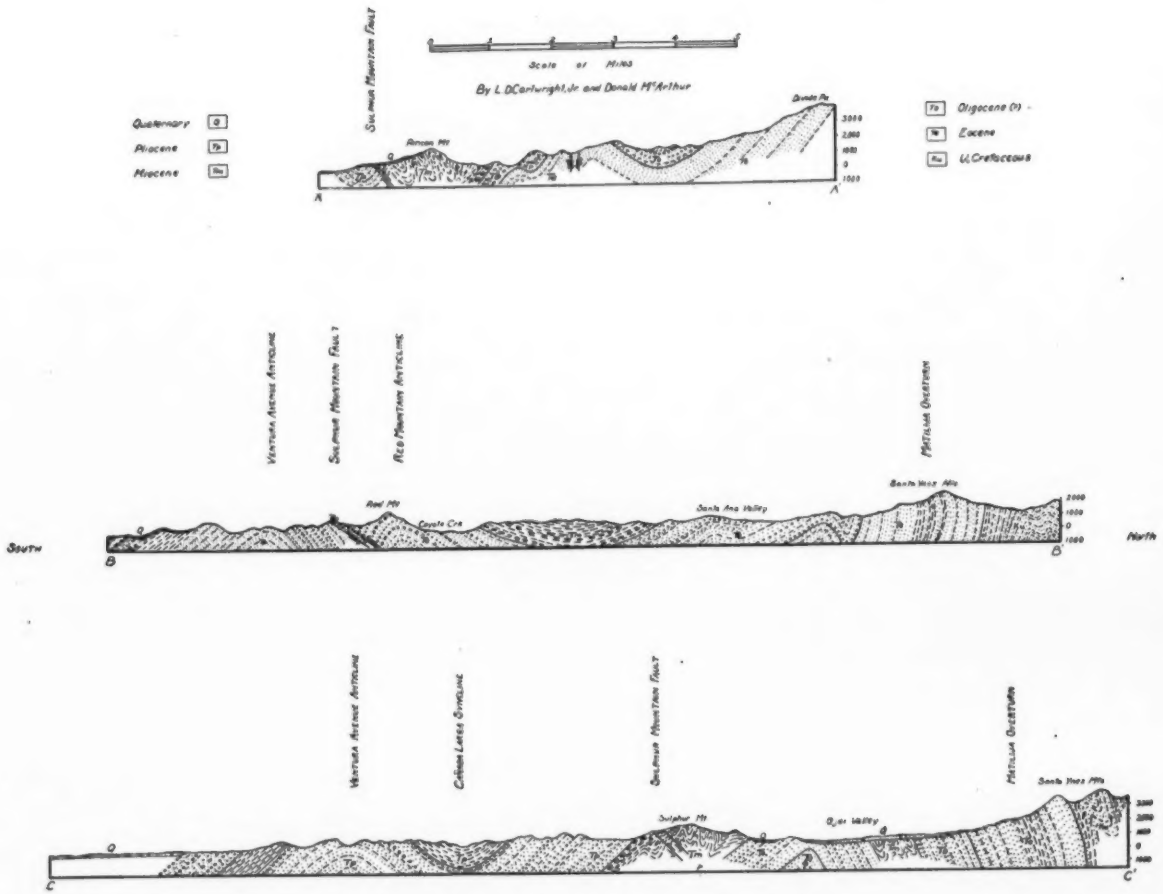

FIG. 1.—Geologic cross-sections of the Ventura quadrangle, California.

carried on in a limited area to learn its character, the source of the detrital matter composing it, and the conditions of deposition. The regional geology of the district is briefly described, and illustrated with a map and sections; and the petrography of the Cretaceous, Eocene, Oligocene(?), and Miocene rocks is discussed. A summary of the general features and correlations of the Pliocene formations is followed by a detailed description of the Pico formation, its depositional structures, composition, and diagenesis. Conclusions are drawn regarding the conditions of origin and deposition of the detrital material.

The work on this subject was done under the direction of Dr. Hubert G. Schenck of Stanford University, to whom the writer is greatly indebted for suggestions and criticisms throughout, and for assistance with the paleontological and stratigraphical problems presented. Among the local geologists whose aid the writer wishes here to acknowledge are T. L. Bailey of the Shell Company and W. S. W. Kew of the Standard Oil Company.

SUMMARY OF THE REGIONAL GEOLOGY[1]

The Ventura quadrangle lies in the mountainous region along the Pacific coast between Santa Barbara and Los Angeles. Its rocks are sedimentary strata of Cretaceous, Tertiary, and Quaternary age, which have been deformed by long folds and thrust faults striking easterly and westerly parallel to the mountain ranges (Fig. 1). The semi-arid climate and scant development of vegetation are favorable to their exposure, and they crop out in long, roughly parallel belts, the formations being youngest along the coast and becoming progressively older toward the north (Fig. 2).

The Cretaceous, Eocene, and Oligocene(?) formations crop out in the northern half of the quadrangle and constitute from 18,000 to 19,000 feet of complex, feldspathic sandstone, silty shale, and conglomerate (Fig. 3). The Miocene formations crop out in the southern part of the quadrangle, just north of the Pico formation, and consist of shale, sandstone, dolomite, and limestone. South of the belt of Miocene outcrop, and separated from the Miocene beds for most of the distance by the Sulphur Mountain fault, are the Pico and Saugus formations of the Pliocene series. The Pico formation, 12,000 feet of slightly lithified marine sandstone, clay, and conglomerate, comprises

[1]A report on the geology of the Ventura quadrangle accompanied by a detailed geologic map has been completed by Paul F. Kerr and H. G. Schenck and will be published later. They are also preparing a report on the geology of the adjacent Santa Clara quadrangle.

FIG. 1.—Geologic cross-sections of the Ventura quadrangle, California.

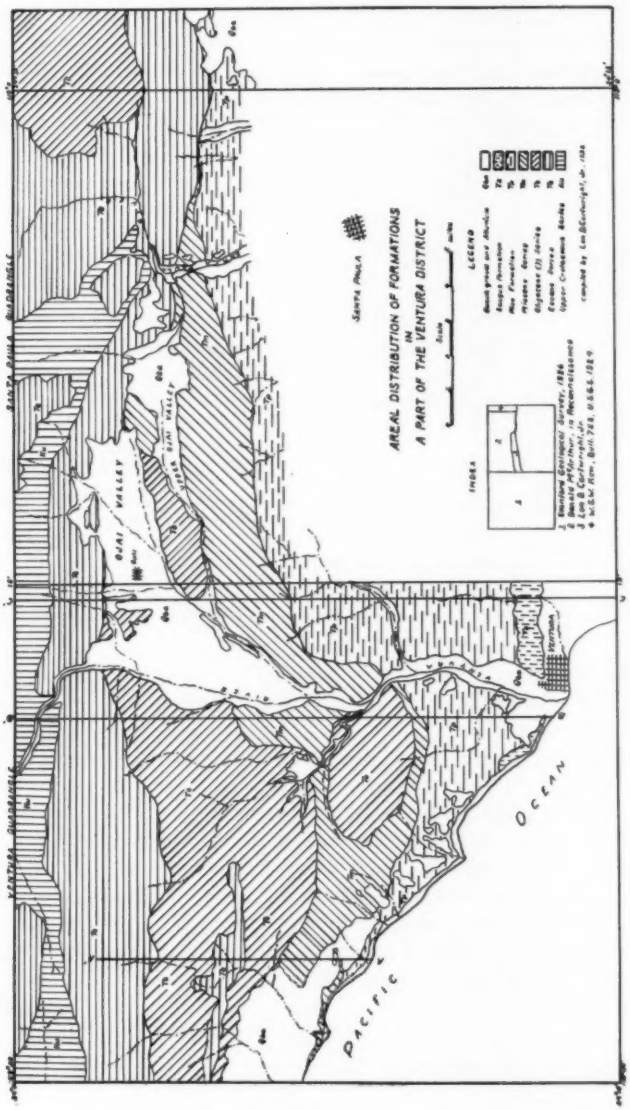

FIG. 2.—Areal distribution of formations in a part of the Ventura district.

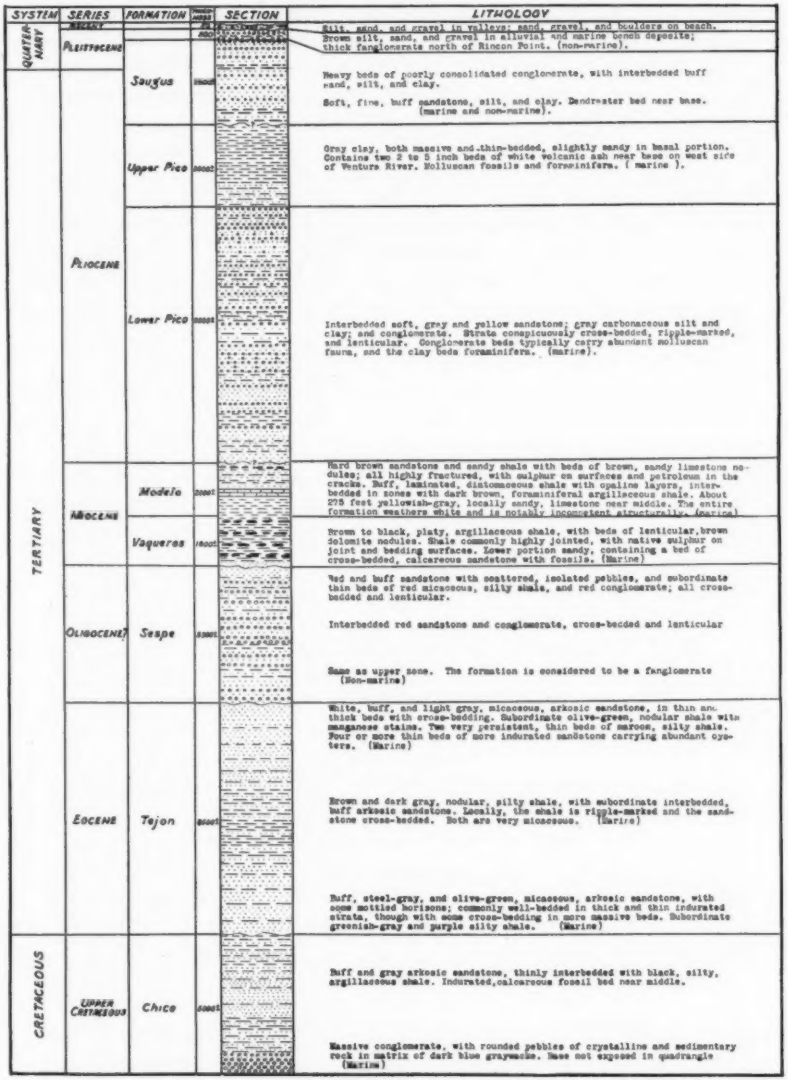
SYSTEM
SERIES
FORMATION
SECTION
LITHOLOGY
QUATERNARY
RECENT
PLEISTOCENE
TERTIARY
PLIOCENE
MIOCENE
OLIGOCENE?
EOCENE
CRETACEOUS
UPPER CRETACEOUS
Saugus
Upper Pico
Lower Pico
Modelo
Vaqueros
Sespe
Tejon
Chico
Silt, sand, and gravel in valleys; sand, gravel, and boulders on beach.
Brown silt, sand, and gravel in alluvial and marine terrace deposits; thick fanglomerate north of Rincon Point. (non-marine).
Heavy beds of poorly consolidated conglomerate, with interbedded buff sand, silt, and clay.
Soft, fine, buff sandstone, silt, and clay. Dendraster bed near base. (marine and non-marine).
Gray clay, both massive and thin-bedded, slightly sandy in basal portion. Contains two 2 to 5 inch beds of white volcanic ash near base on west side of Ventura River. Molluscan fossils and foraminifera. (marine).
Interbedded soft, gray and yellow sandstone; gray carbonaceous silt and clay; and conglomerate. Strata conspicuously cross-bedded, ripple-marked, and lenticular. Conglomerate beds typically carry abundant molluscan fauna, and the clay beds foraminifera. (marine).
Hard brown sandstone and sandy shale with beds of brown, sandy limestone nodules; all highly fractured, with sulphur on surfaces and petroleum in the cracks. Buff, laminated, diatomaceous shale with opaline layers, interbedded in zones with dark brown, foraminiferal argillaceous shale. About 275 feet yellowish-gray, locally sandy, limestone near middle. The entire formation weathers white and is notably incompetent structurally. (marine)
Brown to black, platy, argillaceous shale, with beds of lenticular, brown dolomite nodules. Shale commonly highly jointed, with native sulphur on joint and bedding surfaces. Lower portion sandy, containing a bed of cross-bedded, calcareous sandstone with fossils. (Marine)
Red and buff sandstone with scattered, isolated pebbles, and subordinate thin beds of red micaceous, silty shale, and red conglomerate; all cross-bedded and lenticular.
Interbedded red sandstone and conglomerate, cross-bedded and lenticular
Same as upper zone. The formation is considered to be a fanglomerate (Non-marine)
White, buff, and light gray, micaceous, arkosic sandstone, in thin and thick beds with cross-bedding. Subordinate olive-green, nodular shale with manganese stains. Two very persistent, thin beds of maroon, silty shale. Four or more thin beds of more indurated sandstone carrying abundant oysters. (Marine)
Brown and dark gray, nodular, silty shale, with subordinate interbedded, buff arkosic sandstone. Locally, the shale is ripple-marked and the sandstone cross-bedded. Both are very micaceous. (Marine)
Buff, steel-gray, and olive-green, micaceous, arkosic sandstone, with some mottled horizons; commonly well-bedded in thick and thin indurated strata, though with some cross-bedding in more massive beds. Subordinate greenish-gray and purple silty shale. (Marine)
Buff and gray arkosic sandstone, thinly interbedded with black, silty, argillaceous shale. Indurated, calcareous fossil bed near middle.
Massive conglomerate, with rounded pebbles of crystalline and sedimentary rock in matrix of dark blue graywacke. Base not exposed in quadrangle (Marine)

FIG. 3.—Tentative generalized columnar section of Ventura quadrangle, by L. D. Cartwright, Jr., and Donald McArthur, 1926.

most of the series, and is unconformably overlain by 2,000 feet or more of Saugus sandstone, clay, and conglomerate. Together, these formations comprise the Fernando group in this district. They are unconformably overlain by bench deposits of Pleistocene gravel and by Recent alluvium.

PRE-PLIOCENE FORMATIONS

The formations of this immediate region older than the Pliocene are of interest in this problem, because it is possible to demonstrate that they have been the source of the material of the Pico formation. The evidences for the assigning of these formations to their respective ages, and for the adoption of the formation names are not discussed as they are not pertinent to the problem. Later paleontologic studies in this region will doubtless show further divisions of some of these formations, and may justify a revision of the nomenclature here used.

Chico formation.—The oldest beds exposed in the quadrangle comprise the Chico formation, of Upper Cretaceous age, and consist of 650 feet of conglomerate, overlain by about 4,500 feet of interbedded hard sandstone and shale. The conglomerate consists of ovoid pebbles averaging 4 inches in diameter, set in a matrix of dark blue graywacke. The pebbles represented, by field determination, are: granite, alaskite, rhyolite, dolerite, olivine-gabbro, gneiss, quartzite, quartzitic conglomerate, and sandstone.

The Chico sandstones consist principally of quartz and feldspar, which occur in equal quantities and form 90 to 95 per cent of the grains. Weathered biotite flakes are quite prominent; and chalcedony, muscovite, and zircon are present but not conspicuous. The shales are in large part siltstones, and are similar in mineralogy to the sandstones.

The distinctive megascopic characteristics of the Chico rocks are: (1) conspicuous induration, (2) thin-bedding and platy fracture, (3) gray to black color of many of them, and (4) scarcity of fossils.

The chief microscopic characteristics are: (1) angularity of grains in the sandstones, (2) good sorting displayed by medium and fine sandstones, (3) high proportion of feldspar grains, which are commonly moderately weathered, and (4) prominence of carbonaceous matter.

Tejon formation.—The Tejon formation, of Eocene age, consists of 8,500 feet of interbedded buff, white, and gray sandstones and olive-green, brown, and gray shales, with sandstones predominating. In the upper part of it there are four beds of indurated, oyster-bearing sandstone, and a local development of pebble-conglomerate.

The mineralogy of these rocks is notably complex. Quartz and feldspar, the latter considerably sericitized, comprise 80 to 90 per cent of the grains. Biotite is the most prominent accessory, and epidote, pyroxene, muscovite, chalcedony, and chlorite are conspicuous. The minor accessories noted are zircon, apatite, basaltic hornblende, titanite, staurolite, garnet, calcite, tourmaline, hornblende, and metallic iron minerals. The gray rocks contain considerable carbonaceous matter.

A field examination of one of the conglomerate beds revealed the following rocks represented as pebbles: chert, acidic and basic porphyry, granitic rock, quartzite, quartz, sandstone, and serpentine.

The distinctive megascopic characteristics of the Tejon rocks may be summarized as follows: (1) prevailing buff, light gray, and mottled colors of the sandstones, and green, brown and gray colors of the shales; (2) a great amount of quartz, feldspar, and biotote; and (3) four indurated, calcareous, oyster-bearing sandstones in the upper portion of the series.

The chief microscopic characteristics are: (1) prevailing angularity of the grains, (2) prominence of feldspar, moderately to considerably weathered, and (3) abnormally large concentration of heavy minerals, especially in the lower sandstone beds.

Sespe formation.—The Sespe formation, of Oligocene(?)[1] age, consists of 5,000 feet of interbedded conglomerates, sandstones, and shales, for the most part red in color, and considered to represent an ancient fanglomerate. From the conglomerates the writer collected and identified the following rocks represented as pebbles: granite, rhyolite porphyry, granodiorite, alaskite, syenite, basic porphyry, gneiss, mica schist, quartzite, serpentine, chert, organic limestone, sandstone, graywacke, greenstone, and glaucophane schist.

In the Sespe sandstones quartz and feldspar, the latter commonly weathered and almost as plentiful as the quartz, form from 75 to 90 per cent of the grains. Chert is prominent, forming from 3 to 15 per cent of the grains. The ferromagnesian minerals are relatively plentiful, particularly biotite. Muscovite, chlorite, epidote, pyroxene, titanite, garnet, magnetite, and grains of a dense green igneous rock are present in different proportions. About 1/5 of the rock is matrix, composed of finely comminuted mineral matter, clay, and chalcedony.

[1]The recent discovery by Stock and Furlong of vertebrate remains including *Promerycochoerus* and *Leptauchenia* 600 feet from the top of the Sespe formation on South Mountain indicates that the upper part of the formation is Miocene in age. The lower, larger part, however, is still doubtfully assigned to the Oligocene.

The Sespe shales are silty, in many places sandy, and characteristically micaceous.

The distinctive megascopic characteristics of the Sespe rocks are: (1) predominance of red coloration, (2) abundance of mica, (3) absence of fossils, and (4) induration of most of the rocks.

The chief microscopic characteristics are: (1) poor sorting of the grains, (2) prominence of chert, commonly darkened by various pigments, as grains, (3) presence of a matrix of comminuted mineral matter, clay, and chalcedony, (4) weathered condition of the feldspars, and (5) red stains on the grains and in the matrix.

Vaqueros formation.—The Vaqueros formation comprises about 1,800 feet of strata, the basal part of which consists of soft, buff sandstone, locally cross-bedded, and buff, silty shale, and contains an indurated bed of calcareous, cross-bedded sandstone from 4 to 20 feet thick, which carries many marine fossils. The strata above this bed are more argillaceous, and grade into a dark brown to black, brittle, platy shale with beds of lenticular, brown dolomite nodules as much as 1 foot thick and 25 feet long.[1]

The distinctive megascopic characteristics of the Vaqueros are: (1) buff sandstone, poorly assorted, locally cross-bedded, and pebbly, and containing diagnostic, megascopic, marine fossils, (2) black, brittle, argillaceous shale, commonly with ferric oxide stain and native sulphur on the joint faces, and containing a few minute fossils, and (3) hard, brown, nodular dolomite in discontinuous beds in the shale.

The chief microscopic characteristics are: (1) equal proportions of quartz and chert in the sandstone, with common though less plentiful feldspar, moderately to highly weathered, and a little biotite and chlorite, (2) fragments of mollusca, echinoderms, foraminifers, and possibly bryozoans in the fossiliferous sandstone bed, (3) dense argillaceous shale, with disseminated brown and black pigment, and (4) dense brown dolomite, with equigranular, interlocking, subhedral crystals.

Modelo formation.—The Modelo formation comprises some 2,000 feet of shale, sandstone, and limestone overlying the Vaqueros. The upper part of the formation consists of hard, brown, medium-grained, quartzose sandstone and brown to black, brittle, locally sandy shale with beds of brown limestone nodules greatly resembling the dolomite nodules of the Vaqueros formation. The lower part of the formation

[1]Recent field work by T. L. Bailey has shown that *Turritella ocoyana* occurs in this shale series, indicating Temblor age for a part of it. It is probable that the Temblor portion extends up into and includes a part of, the diatomaceous shales here discussed under the Modelo formation.

consists of light buff, laminated, organic shale with banded opaline layers, interbedded with black, foraminiferal, argillaceous shale and buff to brown bedded limestone. The Modelo is locally very petroliferous, and associated with these petroliferous zones are outcrops of shale which has been fused to a red and black, in many places scoriaceous, rock, by the burning of the oil.

The distinctive megascopic features of the Modelo formation are: (1) hard, brown, medium-grained, quartzose sandstone, (2) hard, dense, gray-buff to brown limestone, both well-bedded and in nodules, (3) pale buff, faintly banded, foraminiferal shale, generally of low specific gravity and with high absorption properties, (4) brown, banded opaline shale, brittle and white-weathering, (5) black, brittle, argillaceous shale with free sulphur on fracture surfaces, (6) many fish scales, and a few marine molluscan fossils, and (7) red to black, generally scoriaceous, burnt shale.

The chief microscopic characteristics are: (1) nodular limestone of minutely laminated, finely granular calcite, and a few disseminated detrital grains, (2) well-bedded limestone of coarser-grained calcite, with much foraminiferal and other fossil debris, and detrital grains, (3) dense and cloudy organic shale with fossil remains of calcite and silica, and a few detrital grains, (4) opal shale consisting of brown bands of opal with foraminiferal remains of calcite and chalcedony scattered through it, and (5) scoriaceous burnt shale consisting of porous, isotropic glass, with scattered, detrital grains, and red and black flecks.

PLIOCENE FORMATIONS OF THE VENTURA QUADRANGLE

The Pliocene series of this district is divided into the Pico and Saugus formations, which, following usage already established, comprise the Fernando group. The Pico formation was defined by Kew[1] as the marine formation consisting "mainly of both fine and coarse-grained sandstones with a few interbedded strata of conglomerate" resting unconformably on the Modelo formation, and overlain unconformably by the Saugus formation. It is well exposed in Pico Canyon, the type locality, 38 miles east of the Ventura quadrangle. In Elsmere Canyon, 5 miles east of Pico Canyon, large collections of fossils were made from it which indicated its lower Pliocene age.

The Saugus formation, as now understood, constitutes the upper part of the Fernando group, and is itself unconformably overlain by

[1]W. S. W. Kew, "Geology and Oil Resources of a Part of Los Angeles and Ventura Counties, California," *U. S. Geol. Survey Bull. 753* (1923), p. 69.

Pleistocene terrace deposits.[1] Its type locality is in the vicinity of Saugus, 45 miles east of the Ventura quadrangle. Kew describes it as being "uniform in lithology, consisting mainly of light-colored gravel and sand, usually more or less unconsolidated, with interbedded soft, fine sandstone." It contains a younger fauna than the Pico formation, and extends up into the Pleistocene.

Although Kew recognized but one formation below the Saugus in the Fernando group, the writer found it expedient to subdivide the Pico of the Ventura quadrangle into lower and upper members. Future detailed paleontologic work will probably demonstrate that faunal zones may be differentiated as well.

Lower Pico.—The Lower Pico consists of 9,300 feet of unlithified, interbedded sandstone, clay, and conglomerate, where it is exposed along the divide between Canada de Aliso and Coche Canyon. This is the only part of the quadrangle where the base of the formation is exposed, faulting having concealed it at other places (Fig. 4). As exposed here and immediately east in the Santa Paula quadrangle, the contact with the underlying Modelo formation is either an obscure unconformity without appreciable change in attitude of the beds, and without prominent erosional irregularities on the surface of the older formation, or a conformable contact. The only field evidence of unconformity found is the presence of pebbles of identifiable Modelo shale and limestone in conglomerate beds of the lower Pico; but since these pebbles could have been derived from Modelo beds exposed along the margin of a lower Pico sea and swept into a basin in which continuous sedimentation was taking place, their evidence is inconclusive. Some geologists consider continuous deposition to have taken place from Modelo to Pico time, in which case beds of uppermost Miocene age must be present. This problem is being studied by David L. Evans of the Stanford Geological Survey. The top of the lower Pico, wherever exposed in the quadrangle, is a bed of conglomerate or conglomeratic sandstone. The upper Pico overlies this conformably, but with a sharp lithologic break.

The lower Pico carries a fauna of marine gastropods and pelecypods[2] in the conglomerates and sandstones and of foraminifers in the clays. The fossils indicate that the member was deposited in lower Pliocene time, possibly in cool temperate waters.

[1] W. S. W. Kew, *op cit.*, p. 81.

[2] The molluscan fauna is being described in a paper by Louis N. Waterfall, now in the University of California Press.

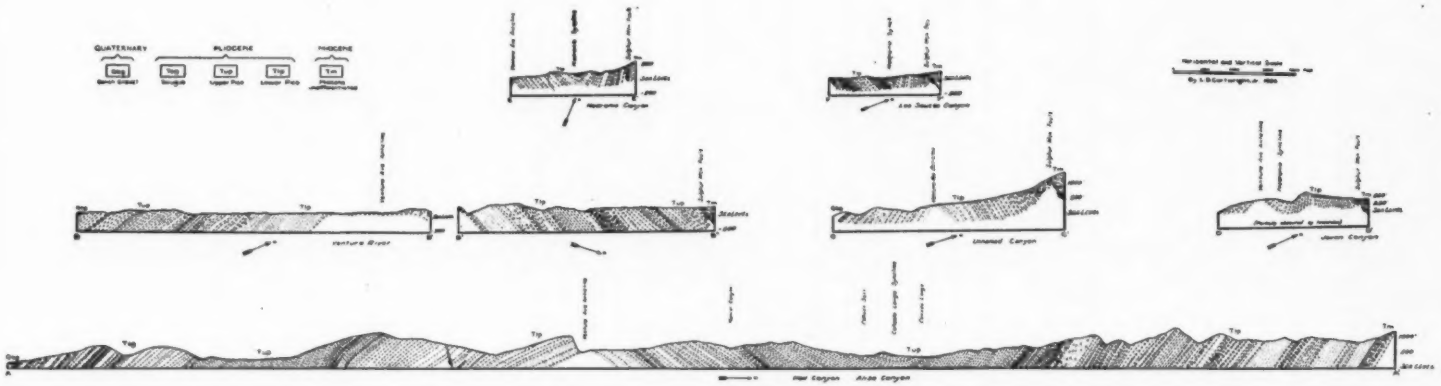

FIG. 4.—Geologic sections of Pliocene in Ventura quadrangle.

Upper Pico.—The upper Pico consists of 3,000 feet of massive and thin-bedded clay, slightly sandy in the lower portion. It is best exposed in the middle course of Hall Canyon, in the southeast part of the quadrangle. Its lower contact, though conformable, is represented by a sharp lithologic break between the sandy clay of its base and the heavy conglomerate at the top of the lower Pico. At its upper contact an angular unconformity is suggested, above which lie the fine silts and sands, and the *Dendraster* reef of the basal Saugus. This unconformity is not pronounced, since both formations are tilted to the south here, but is indicated by a slight variance in the dip and strike of the two formations.

Although in the Ventura quadrangle the Pico formation is easily divided into two members of contrasting lithology, it is not thus divisible upon lithology in other parts of the district. The clay beds of the upper Pico in the trough of Canada Larga syncline (Fig. 5) change in lithology to the eastward, and 5 miles from the Ventura quadrangle they were found by Bailey[1] to "contain a number of coarse, massive, and thick conglomerates, which appear identical with the conglomerates found farther down in the Pico formation." The east-west striking clay beds of the upper Pico south of the axis of the Ventura Avenue anticline are lithologically distinct in the Adams Canyon section, 8 miles east of the Ventura quadrangle; but where Bailey identified the same horizon paleontologically on South Mountain, several miles east and south of the outcrop in Adams Canyon, the beds consisted of blue-gray silts and argillaceous sandstones for the most part, with 10 to 25 per cent of intercalated sandstones and conglomerates.

Marine pelecypods, gastropods, and foraminifers are found throughout the upper Pico member, and establish its Pliocene age. Present data indicate that the molluscan faunas of the two members of the Pico formation are distinctly different.

The beds of the lower Pico member of the Pico formation were traced eastward across the Santa Paula quadrangle into the beds mapped as Pico by Kew[2], thus definitely demonstrating that they are of the same age (Fig. 2). The exact correlative of the upper Pico is not at present known.

Saugus.—The Saugus formation exposed in this quadrangle consists of about 2,000 feet of strata. The lower fourth of the formation consists of soft, fine, buff sandstone, silt, and clay, with a prominent

[1]T. L. Bailey, written communication of Dec. 9, 1926.

[2]W. S. W. Kew, *op. cit.*, geologic map.

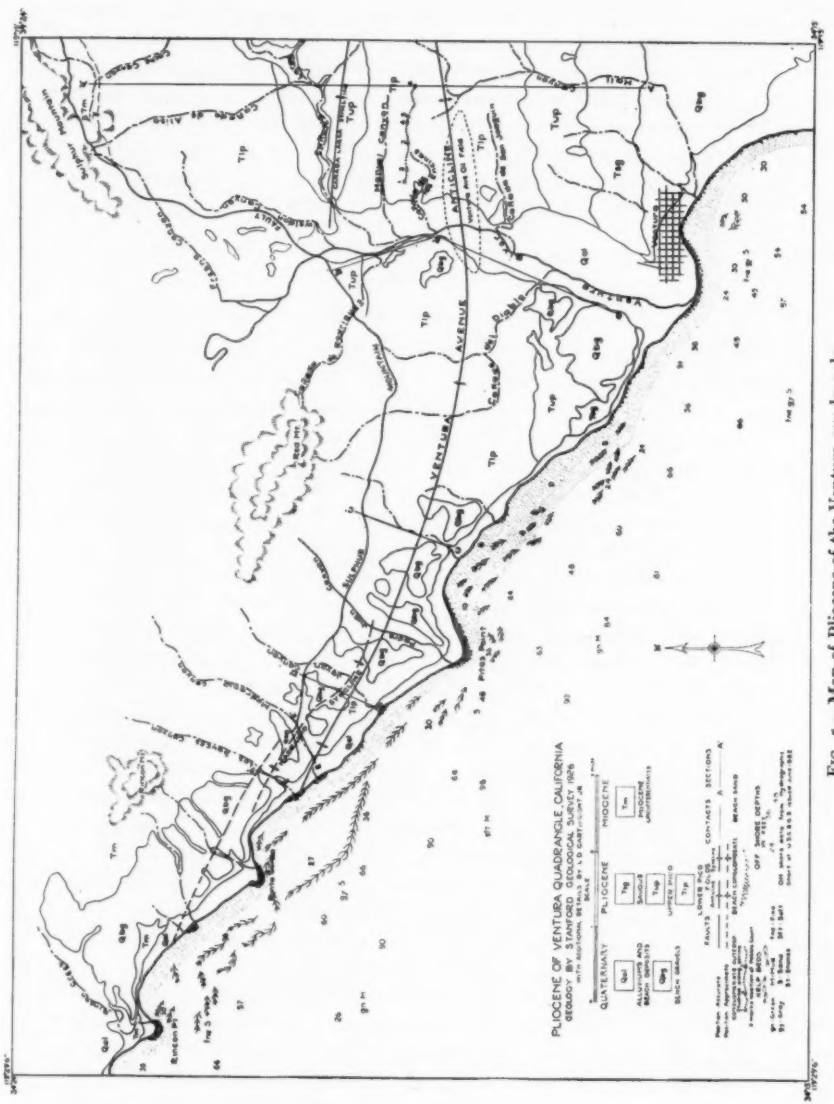

FIG. 5.—Map of Pliocene of the Ventura quadrangle.

Dendraster bed near the base. The upper three-fourths of it consist of heavy beds of poorly consolidated conglomerate, with interbedded buff sand, silt, and clay. The deposits forming it are of both marine and (to a lesser degree) non-marine origin. The Saugus is well exposed in the lower part of Hall Canyon, south of the outcrop of the upper Pico. Here it lies unconformably over the upper Pico, and is itself unconformably overlain by Pleistocene bench deposits. Its upper limit is nowhere exposed in the quadrangle.

CHARACTERISTICS OF THE PICO FORMATION IN THE VENTURA QUADRANGLE

DEPOSITIONAL STRUCTURES OF THE LOWER PICO

Stratification.—The lower Pico is composed throughout of stratified clastic material, the layers of which range in thickness from 1/20 inch to 30 feet, though few are greater than 3 feet. Bedding planes in it are shown by abrupt change in kind, texture, or color of the constituent material, and, as a rule, are rather prominent. Rhythmic alternations of beds of sandstone and clay, or of conglomerate, sandstone, and clay, which commonly maintain remarkably uniform thickness, in many places persist through hundreds of feet of strata.

Lenticularity.—Lenticularity is a characteristic feature of the lower Pico beds, although in many of the exposures it is not obvious. The large scale development of this feature is illustrated by a comparison of the two columns, *B*-*B'* and *B'*-*B''*, in Figure 6. These columns represent the exposed portions of the lower Pico north and south of the Ventura Avenue anticline, along Ventura River, and are equivalent because they are measured from the same point on the axis of the fold north and south, respectively, to the base of the upper Pico (Fig. 4). The section north of the axis is 4,460 feet thick, and contains coarser-grained sediments and many features of near-shore deposition absent in the beds of the southern section, which is but 3,190 feet thick. A thinning of 1,270 feet, or 28 per cent, is illustrated by these sections, the upper limits of which are but 3 miles apart. This indicates that the land-mass supplying the clastic material was situated north of this portion of the basin of deposition, and relatively close to it.

Lenticularity of a lower order of magnitude is noticeable at some outcrops, individual beds of conglomerate or sandstone as much as 3 or 4 feet thick lensing out entirely within 30 feet. Most of the examples of this type were found in the conglomeratic phase of the lower Pico. These lenses and the adjacent strata showed many characteristics

of current deposition, such as festooned cross-bedding, scour channels, and small, pebbly pockets. Such features are typical of fanglomerates and deltas, and can result from deposition by a marine current in a shifting channel. Marine fossils are relatively plentiful in these con-

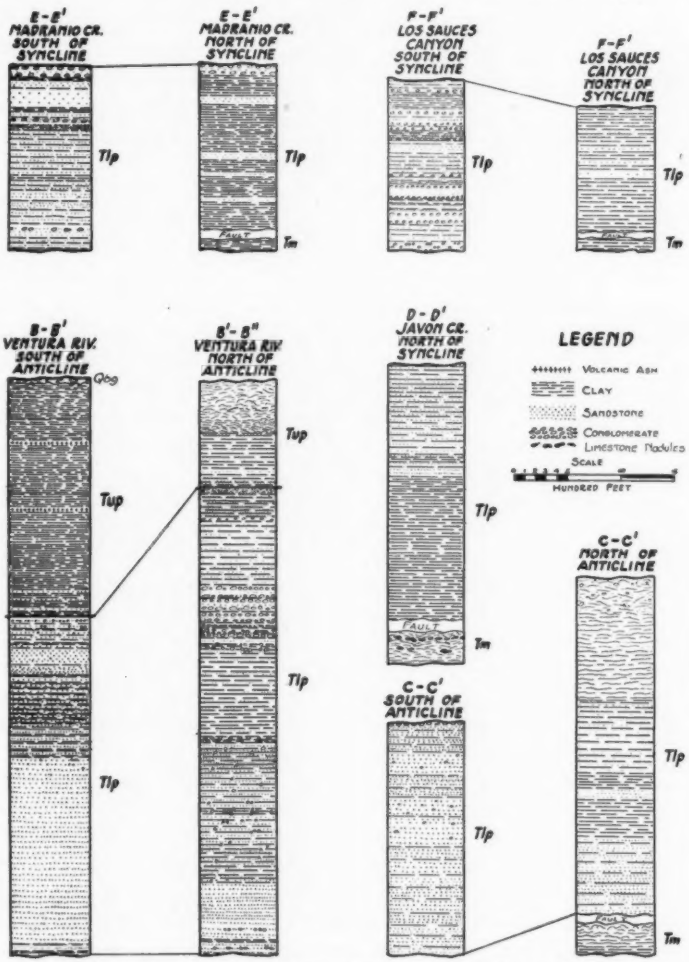

FIG. 6.—Geologic columns of incomplete Pliocene sections in the Ventura quadrangle.

glomeratic horizons, so that a marine site of deposition for these beds, possibly the subaqueous slope of a delta building out into the ocean, is inferred.

Structures within beds.—Certain of the massive sandstone beds, especially in the zones where rhythmic alternation of strata is apparent, show a gradation in grain size from coarse at the bottom to fine at the top. The scoured and eroded upper surface of the first bed is in turn overlain by the coarse, pebbly base of the next bed. Each bed represents a cycle of deposition in which the force of the transporting agent bringing the detritus commences at a maximum and decreases gradually to a minimum.

Cross-lamination on a large and a small scale is a common though by no means universal structure in the sandy beds. Many of the laminae in successive beds slope in different directions, in 5 feet of beds as many directions of slope being represented. Part of the cross-lamination may be attributed to deposition on the front of a delta or the lee side of any irregularity on the bottom, but much of it, especially where different directions of slope are represented, appears to represent remnants of sand-bars which have shifted back and forth (Fig. 7).

Many minor-order structures such as diminutive lenses of clay and sand, minutely cross-bedded, occur throughout the lower Pico beds and indicate deposition in relatively shallow agitated water. Minature folds as high as 3 inches and as long as 20 inches are not uncommon within the thicker beds, and represent original deposition over an irregularity, or differential compacting of sand pockets in clay.

Structures along bedding planes.—Eroded bedding planes are not uncommon in the lower Pico. These surfaces of contemporaneous erosion, although structures of a decidedly minor order, differ considerably in relief and extent, illustrating the changing strength of the currents, which first deposited detritus and later picked it up and shifted it elsewhere. Symmetric and asymmetric ripple marks, formed by waves and currents, are of common occurrence throughout the beds, indicating the shallow depth and the agitation of the water in which they were deposited. Rows of thin, flat, clay galls lie parallel to the bedding in some of the sandstones, and probably represent the remnants of thin clay layers in which mud cracks developed. Such an inferred origin suggests that parts of the surface of deposition were occasionally exposed to the atmosphere, possibly as mud flats.

Conglomerates.—The depositional structures of the lower Pico beds afford the best criteria for interpreting the conditions under which the

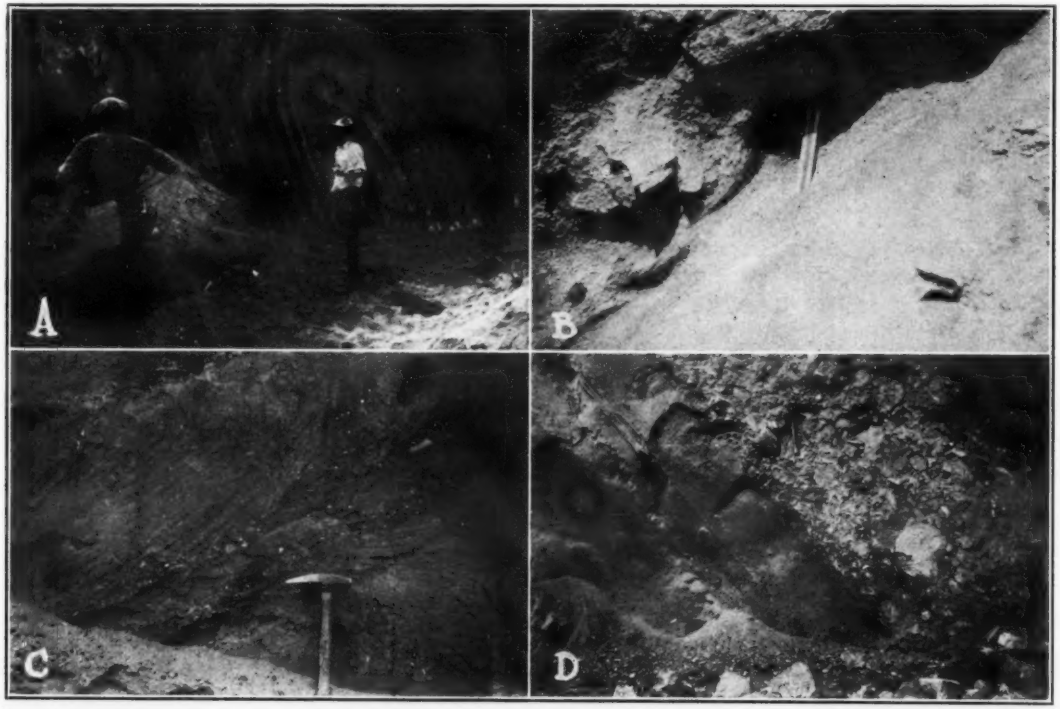

FIG. 7.—Photographs showing depositional structures of Pico formation. *A*, alternating beds of sandstone and clay, forming part of a series showing rhythmic alternation of conditions of deposition. *B*, lens of dark clay deposited as a fold over a wave ripplemark in sandstone. *C*, conglomeratic sandstone showing cross-lamination, the laminae of which slope in different directions. *D*, argillaceous conglomerate with a large boulder of contemporaneous clay near bottom of bed. Lower Pico.

detritus was laid down, and for this reason the conglomerates, which comprise 4,000 feet of the 9,300-foot Canada de Aliso section (Fig. 8), are considered in the structural as well as the compositional sense. Three types of conglomerate are recognized, representing three modes of deposition, namely, deltaic, littoral, and gravity flow.

The conglomerates considered to have been laid down on a delta form zones as much as 500 feet thick comprised of sandy conglomerate

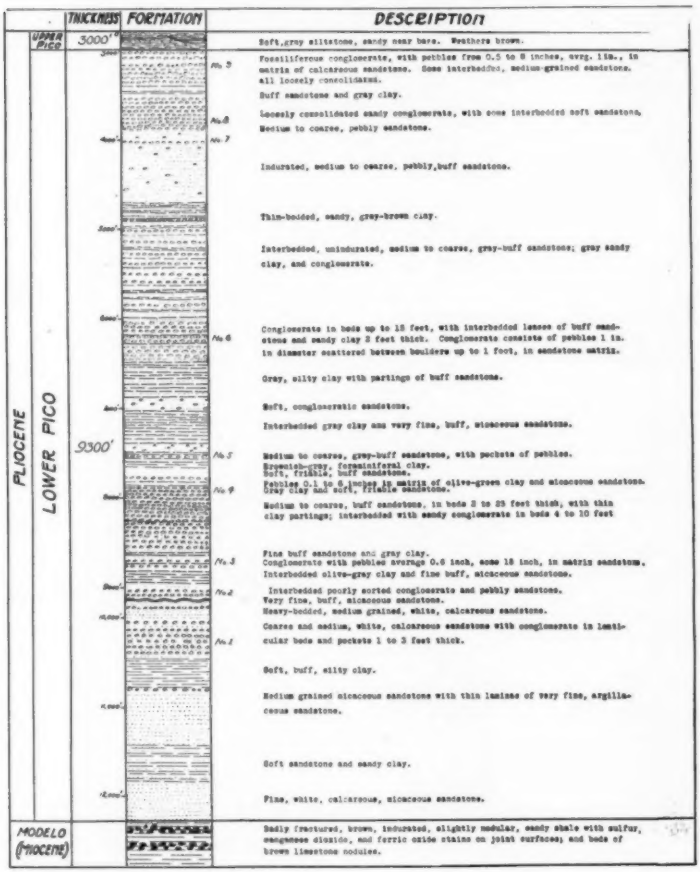
THICKNESS
FORMATION
DESCRIPTION
PLIOCENE
UPPER PICO
LOWER PICO
3000'
9300'
MODELO (MIOCENE)
Soft, gray siltstone, sandy near base. Weathers brown.
Fossiliferous conglomerate, with pebbles from 0.5 to 8 inches, avrg. 1½., in matrix of calcareous sandstone. Some interbedded, medium-grained sandstone, all loosely consolidated.
No. 9
Buff sandstone and gray clay.
No. 8
Loosely consolidated sandy conglomerate, with some interbedded soft sandstone.
No. 7
Medium to coarse, pebbly sandstone.
Indurated, medium to coarse, pebbly, buff sandstone.
Thin-bedded, sandy, grey-brown clay.
Interbedded, unindurated, medium to coarse, gray-buff sandstone; gray sandy clay, and conglomerate.
No. 6
Conglomerate in beds up to 15 feet, with interbedded lenses of buff sandstone and sandy clay 2 feet thick. Conglomerate consists of pebbles 1 in. in diameter scattered between boulders up to 1 foot, in sandstone matrix.
Gray, silty clay with partings of buff sandstone.
Soft, conglomeratic sandstone.
Interbedded gray clay and very fine, buff, micaceous sandstone.
No. 5
Medium to coarse, grey-buff sandstone, with pockets of pebbles.
Brownish-gray, foraminiferal clay.
Soft, friable, buff sandstone.
No. 4
Pebbles 0.1 to 6 inches in matrix of olive-green clay and micaceous sandstone. Gray clay and soft, friable sandstone.
Medium to coarse, buff sandstone, in beds 2 to 25 feet thick, with thin clay partings; interbedded with sandy conglomerate in beds 4 to 10 feet
Fine buff sandstone and gray clay.
No. 3
Conglomerate with pebbles average 0.6 inch, some 18 inch, in matrix sandstone.
Interbedded olive-gray clay and fine buff, micaceous sandstone.
No. 2
Interbedded poorly sorted conglomerate and pebbly sandstone.
Very fine, buff, micaceous sandstone.
Heavy-bedded, medium grained, white, calcareous sandstone.
No. 1
Coarse and medium, white, calcareous sandstone with conglomerate in lenticular beds and pockets 1 to 3 feet thick.
Soft, buff, silty clay.
Medium grained micaceous sandstone with thin laminae of very fine, argillaceous sandstone.
Soft sandstone and sandy clay.
Fine, white, calcareous, micaceous sandstone.
Badly fractured, brown, indurated, slightly nodular, sandy shale with sulfur, manganese dioxide, and ferric oxide stains on joint surfaces; and beds of brown limestone nodules.

FIG. 8.—Columnar section along Aliso Canyon, north of syncline, section, *A-A'*.

beds from 2 to 15 feet thick, interbedded with sandstone 2 feet thick and clay beds as much as 10 inches thick. They consist of poorly sorted, irregular, and angular to round and smooth pebbles, averaging 1 inch in diameter but ranging up to 1 foot, which are set in a matrix of sandstone. The beds are very lenticular, show cut-and-fill structures, and are interbedded with lenses of cross-laminated sandstone and lignitic clay. Marine fossils occur in individual conglomerate beds at intervals in the series. The zones thicken and thin appreciably along the strike, which in this case corresponds in general with the old strand line, and lens out down the dip, away from the strand.

The great thickness of some of these conglomeratic zones, the poor assortment of the material, the angularity of some of the pebbles, the lenticularity of many of the layers, and the many features of current bedding are suggestive of a subaereal origin. The presence of marine fossils, however, considered with the preceding evidence, favors the hypothesis that this conglomeratic series was deposited on the subaqueous slope of a delta, which subsided as deposition took place.

The second type of conglomerate mentioned is represented by beds ranging from a few inches to 10 or 15 feet thick, interstratified with even-bedded sandstone and clay. Such conglomerates consist of pebbles and boulders ranging in diameter from a fraction of an inch to a foot and a half, but averaging 1 or 2 inches. The pebbles commonly show the effect of considerable attrition, and are sub-rounded. They are not well sorted as to size, the smaller filling the spaces between the larger, and are set in matrices of sandstone. Marine fossils and fossil fragments occur in these beds, and considered with the thinness of the conglomerate strata, the absence of uneven bedding, and the worn shapes of the pebbles, suggest a littoral site of deposition for the beds.

One type of conglomerate which occurs commonly in the lower Pico, consists, in its most distinctive form, of unassorted pebbles disposed without arrangement in a matrix of clay. It grades into the sandy conglomerate type through stages showing rude bedding and an increasingly large proportion of sand in the matrix. The beds range in thickness from less than a foot to 20 or more feet, and commonly show considerable change both in thickness and character along the strike, which corresponds approximately with the old strand line. Well-preserved marine molluscan fossils are typically present in these conglomerates. The interbedded sandstones and clays are very lenticular and generally carbonaceous and lignitic.

The utter lack of assortment shown by these beds, and the random disposition of their pebbles, indicate that the transporting force lacked the sorting power of running water, and that the material was buried immediately after dpeosition before it could be re-worked by waves and currents. Gravity flows, such as take place at present along the cliffed coast of California, are considered to have brought the detritus to the site of deposition, where conditions of rapid sedimentation buried it before it could be re-worked.

Clay boulders and "pudding balls."—The lower Pico conglomerates contain some pebbles and boulders of clay closely resembling in lithology the clay of associated beds. They are commonly somewhat rounded. A few of them, termed here "pudding-balls," are studded with small rock pebbles, and some contain concentric bands of pebbles on the inside. These pudding-balls were probably formed by accretion around a clay nucleus, such as a flake curling up between dessication cracks, which was caught by the renewed flow of a stream over its muddy bed, or by the wash of sea water over a mud-flat.

DEPOSITIONAL STRUCTURES OF THE UPPER PICO

Stratification.—The upper Pico in the Ventura quadrangle has almost none of the depositional structures which characterize the lower Pico, but consists of about 3,000 feet of monotonously even-bedded clay. In fresh cuts the visible bedding planes average 6 feet apart, and in some places are as much as 20 feet apart. In weathered outcrops, however, the bedding is seen to be much thinner, ranging from 3/10 inch to 1 foot.

Salt amygdules.—Many of the clay beds contain small, smooth-walled cavities, two or three millimeters in diameter, somewhat resembling the cavities in amygdaloidal lavas. Each is a closed compartment, the walls of which are lined with minute white crystals of sulphate of magnesia and soda. They are disposed without relation to fissure systems or any diagenetic feature, and probably represent residual salts from minute pockets of occluded water.

Lateral variation.—The whole of the upper Pico crops out only in the belt south of the axis of the Ventura Avenue anticline, and is well exposed only in Hall Canyon. So far as can be observed it maintains a constant thickness of about 3,000 feet, and a constant lithologic character in this quadrangle. In Adams Canyon, 8 miles east of the Ventura quadrangle, its thickness and lithology are unchanged.

COMPOSITION OF THE LOWER PICO

Conglomerates.—The lower Pico is composed of conglomerate, sandstone, and clay representing accumulated rock waste from land masses exposed to erosion north of the Pliocene basin. Because the conglomerate pebbles can be identified with formations exposed north of the present Pliocene outcrop, and because their size facilitates field study, the conglomerate beds have received the most attention.

A quantitative study of the composition of the conglomerates was carried on by field "pebble counts," in each of which 100 pebbles were selected from an outcrop and classified. The number of times each rock type occurred in the hundred was taken as an estimate of the percentage it formed of the bed. The average composition of the conglomerates, based upon an examination of 3,400 pebbles, is shown in the accompanying chart (Fig. 9), and illustrates the relative proportions of the principal constituents of the coarser phases of the lower Pico.

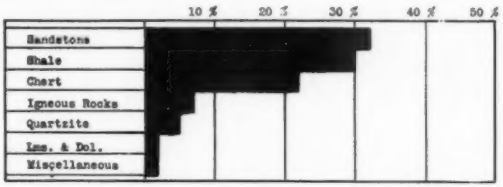

FIG. 9.—Composition of the Pico conglomerates. The results are an average of 3,400 pebbles. The miscellaneous class includes 24 pebbles of quartz, 18 of clay, 8 of gneiss, 7 of lithothamnium limestone, 5 of crystalline limestone, 5 of serpentine, 1 of schist, and 1 of conglomerate.

SUMMARY OF PEBBLE LITHOLOGY

SANDSTONE PEBBLES

Size: ½ to 5 inches diameter, maximum 24 inches.
Shape: sub-rounded to well rounded.
Color: gray, buff, light brown, and green.
Texture: poorly sorted in coarser-grained rock to well sorted in finest-grained; matrix not prominent.
Composition: quartz and feldspar form 75% to 90% of the grains.

Essential Minerals	*Minor Accessory Minerals*
Quartz	Tourmaline
Feldspar	Titanite
orthoclase	Rutile
plagioclase	Magnetite
microcline	Hornblende

Principal Accessory Minerals

Chert
Biotite
Muscovite
Chlorite
Zircon
Augite
Epidote
Apatite
Basaltic hornblende
Hematite
Garnet
Glaucophane
Collophane
Dense igneous rock

Derivation: pebbles from the Tejon and Vaqueros recognized by included fossils; pebbles from the Sespe and Chico recognized from the petrographic character.

SHALE PEBBLES

Size: average 1 inch, none more than 3 inches.
Shape: thin and platy, generally with rounded edges.
Color: buff, brown, and black, many of them weathering white.
Composition: argillaceous, organic, and opal shales.
Derivation: 90% of the pebbles are white-weathering, and commonly carry Modelo fossils, while the balance are probably derived from the Vaqueros, Sespe, Tejon, and Chico formations.

CHERT PEBBLES

Size: average ½ inch, range ¼ to 3 inches.
Shape: commonly sub-rounded to well rounded.
Colors: red, brown, gray, and green.
Composition: principally chalcedony, with less quartz, opal, and impurities. (All examined in thin section carried many *Radiolaria*.)
Derivation: ultimately, from the radiolarian cherts of the Franciscan formation; immediately from the conglomerates of the Sespe, Tejon, and Chico, particularly the Sespe.

IGNEOUS ROCK PEBBLES

Size: average ½ to ¾ inch.
Shape: smooth, sub-rounded to rounded.
Color: principally light and dark gray and black.
Petrography: principally *rhyolitic porphyry*, *auganite porphyry*, and *silicified acid porphyry;* but including diorite, alaskite, granite, syenite, peridotite, granodiorite, gabbro, basalt, and epidote rock.
Derivation: the conglomerates of the Sespe, Tejon, and Chico formations, especially the Sespe.

QUARTZITE PEBBLES

Size: average ½ to ¾ inches diameter.
Shape: rounded to sub-rounded, smooth.
Color: red, pink, white, and gray.
Petrography: sedimentary and metamorphic quartzite.
Derivation: the conglomerates of the Sespe, Tejon, and Chico formations, particularly the Sespe.

LIMESTONE PEBBLES

Size: commonly under 2 inches.
Shape: irregular and rough to round.
Color: gray and brown.
Composition: calcareous limestone and dolomitic limestone (not distinguished in field).
Derivation: Modelo and Vaqueros formations.

LITHOTHAMNION LIMESTONE PEBBLES

Lithology: in general similar to the other limestone pebbles.
Fossils: numerous fossil fragments including the alga *Lithothamnium*, some of the smaller foraminifers, and pelecypods.
Derivation: immediately probably from Sespe conglomerates, ultimately from the Meganos.*

*The discovery of *Lithothamnium* limestone in California was made by H. G. Schenck during a re-examination of organic limestone described by R. N. Nelson (*Univ. of Calif. Dept. of Geol. Bull.*, Vol. 15, No 10 (1925), p. 352), who mapped its occurrence in the upper Santa Ynez River basin and considered it of Meganos (Eocene) age. The discovery was announced in a joint paper by H. G. Schenck and R. N. Nelson, presented before the Le Conte Geological Club, Mar. 6 1926.

A conglomerate bed outcropping east of Ventura River between Manuel Canyon and Canada de las Encinas (see Conglomerate X, Fig. 5) was selected for examination to determine whether or not individual beds were of constant composition, and whether or not composition, as revealed by pebble counts, could be used for correlation of different outcrops. The bed was traced for 1½ miles, and six pebble counts made from it. The accompanying chart (Fig. 10), shows graphically the variation in composition of the bed from station to station.

The conclusions suggested are: that individual conglomerate beds vary considerably in composition along the outcrop; that the composition of a bed at a series of points may show fairly constant features within broad limits; and that it would be unsafe to assign much correlative value to pebble counts until the composition of the bed in question, and of all the other beds with which it might possibly be confused, have been carefully worked out.

A theoretical consideration of the mode of deposition of these conglomerates, however, affords criteria for tentative conclusions regarding their variability. From a study of the depositional structures of the conglomerates, it was concluded that some were of littoral and some of deltaic origin. Conglomerates of the littoral type originate as gravel deposits along a beach. The composition of these gravel deposits varies with the following factors: (1) the location of the deposits with reference to stream mouths; (2) the rocks exposed in the

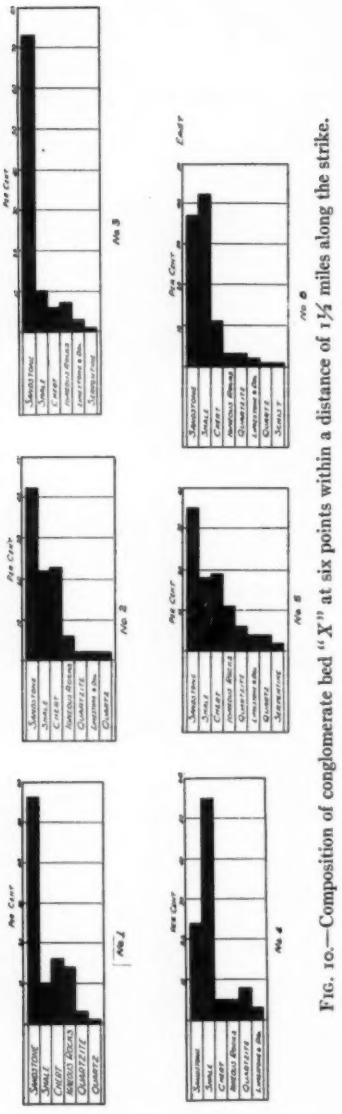

FIG. 10.—Composition of conglomerate bed "X" at six points within a distance of 1½ miles along the strike.

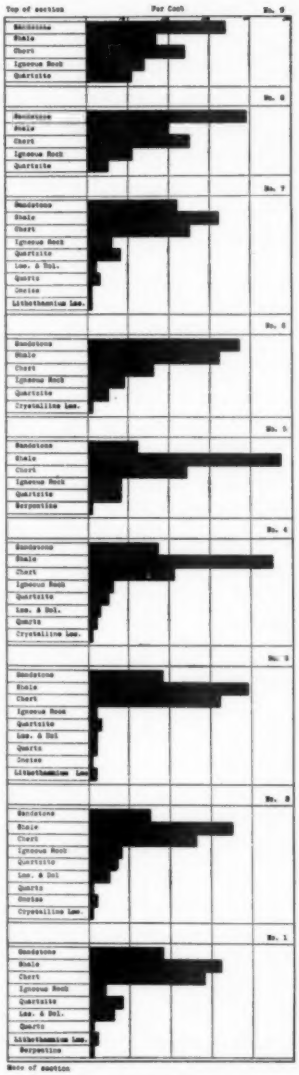

FIG. 11.—Composition of lower Pico conglomerate, Canada de Aliso section.

drainage basins of the streams; (3) the activity of off-shore currents and waves; and (4) the natures of the bottoms where the pebbles are deposited. The gravel deposits now forming on the beach in the Ventura quadrangle (Fig. 5), hence at the same stratigraphic horizon, illustrate the variableness in composition of relatively adjacent littoral conglomerates.

PITAS POINT GRAVEL

(Statistics of pebbles smaller than 6 inches; 95 per cent of the remainder are red sandstone.)

	Per Cent
Shale	57
Sandstone	28
Chert	7
Igneous rock	4
Quartzite	2
Gneiss	2

PUNTA GORDA GRAVEL

Shale	41
Sandstone	34
Chert	11
Igneous rock	6
Quartzite	1
Dolomite and limestone	2
Vein quartz	1
Conglomerate	3
Asphalt	1

RINCON POINT GRAVEL

Sandstone	79
Shale	10
Chert	4
Igneous rock	4
Quartzite	2
Dolomite and limestone	1

Gravels laid down on the marine slope of a delta are controlled by the river which supplies the sediments, and by the marine currents which re-work them. If the currents do not supply other pebbles, derived possibly from another drainage basin on the land-mass, the individual gravel beds may be expected to be of fairly constant composition throughout. Different beds may have different compositions, due to progressive changes in areal geology, topography, and drainage of the basin.

The complete section of the lower Pico exposed in Canada de Aliso (Fig. 8), 9,300 feet of beds, contains a large proportion of conglomerates. The conglomerates were studied statistically, nine pebble counts being made from base to top, at the positions indicated on columnar section *A-A'*. The results of these pebble counts are illustrated diagramatically in Figure 11. The conditions of origin discussed in the last paragraph may exist generally, to the extent that the conglomerate beds along the section *A-A'* are of deltaic origin.

Sandstone.—Sandstone is a very prominent constituent of the lower Pico beds, as reference to the columnar section will show. It may be referred to three general types of fairly uniform character throughout the quadrangle. The most prominent of these is medium- to coarse-grained, gray-buff sandstone, occurring as a rule in beds 6 inches to 2 feet thick. In many places this is interbedded with coarse, gray-buff sandstone having small, pea-sized pebbles either disseminated through it or concentrated in minute lenses 1 or 2 feet long and several inches thick. The third type is fine-grained, yellow sandstone, commonly thinly interbedded or interlaminated with clay.

The medium- to coarse-grained sandstone is light gray upon fresh fracture, and buff to light brown upon weathered surfaces. The gray color is due to disseminated carbonaceous matter, the buff and brown to limonitic staining of the grains developed by oxidation of iron oxide. The rock is commonly friable, and easily crumbled under the fingers, but is hard enough to form steep bluffs. The medium-grained rock is composed of grains from 0.2 to 1.5 millimeters, and is generally fairly well assorted. The coarse-grained contains grains of sand as large as 3 millimeters in diameter and it is less well assorted. The sand grains are sub-angular; that is, uneven and irregular, with the sharp corners and edges somewhat worn away. There is very little matrix, most of the grains being cemented by an inconspicuous amount of clay and some by a little calcite.

The pebbly sandstone differs from the coarse-grained sandstone just described only in having small pebbles disseminated through it or concentrated in small lenses. The pebbles are 5 to 8 millimeters in diameter, well-rounded and smooth, and are composed of chert, quartzite, and dense igneous rock. Where not in lenses the individual pebbles are 1 or 2 inches apart in the matrix of sandstone.

The fine, yellow sandstone owes its color to limonitic stain on the grains, and is generally of one color throughout. Its grains range in size from 0.05 to 0.50 millimeters, averaging 0.10 millimeters, although

some of the sandstone is silty. The grains are angular to sub-angular for the most part, and many show fresh cleavage faces. A few are rounded and a very few are frosted. This type of sandstone occurs in thin beds as much as 6 inches thick, interbedded with gray clay, or thinly interlaminated with clay. Small chips of lignite are common.

The mineralogy of the sandstone beds of the lower Pico is rather uniform throughout. No attempt was made to work out mineralogical peculiarities for the different types of sandstone, and no striking ones were evident from a general microscopic examination of a relatively small suite of specimens.

The following minerals were identified: quartz, feldspar (orthoclase, plagioclase, microcline), chert (green, brown-red, gray), chlorite, magnetite, collophane, epidote, apatite, zircon, tourmaline, garnet, felsitic rock, hornblende, basaltic hornblende, spinel, rutile, augite, calcite, biotite, and muscovite.

Quartz is uniformly the most plentiful constituent mineral, forming from 40 to 60 per cent of the grains. The feldspars, orthoclase, plagioclase, and microcline, in decreasing order of occurrence, form from 20 to 30 per cent of the grains. Ordinarily a large proportion of them are cloudy and sericitized from weathering, but a few are clear and present fresh cleavage faces. Brownish-red, green, and gray chert, many of the grains containing well-preserved *Radiolaria*, constitute from 20 to 30 per cent of the grains. The two minerals, quartz and feldspar, and the rock, chert, constitute from 95 to 99 per cent of the sand grains, and the other minerals previously listed comprise the remainder.

Carbonaceous matter occurs in a finely-divided state in the gray sandstones, and as chips of lignite in all the sandstones, particularly in the fine-grained types. It is impossible to determine anything of the original nature of the vegetal remains, but that they are not necessarily derived from the land is suggested by conditions along the present beach. Kelp beds flourish in the off-shore waters (Fig. 5), and debris from them is continually being washed upon the beach and there buried in the sand. A similar origin is not improbable for a part of the carbonaceous matter in the Pico formation.

A study of the conglomerate pebbles showed that the pre-Pliocene sandstones of the region supplied detrital material to the Pico basins of deposition, and it is inevitable that much of it must have been in the form of sand grains. A comparison of the petrology of the lower Pico sandstones with the petrology of the older sandstones, described earlier in this paper, shows both similarities and dissimilarities. The

petrology of the lower Pico sandstone does not, however, differ appreciably from what might be expected in a sandstone laid down in a basin of deposition, the only material into which it was brought by streams denuding a land-mass composed of the Chico, Tejon, Sespe, Vaqueros, and Modelo sandstones and conglomerates.

The lower proportion of feldspar in the Pico than in most of the older sandstones would result from further weathering and attrition of the already moderately sericitized grains. The weathered biotite of the older sandstones might partly disintegrate, and before final deposition, much of it would be distributed to the argillaceous parts of the basin. The quartz and chert would undergo concentration because of their durability. The high concentration of heavy minerals in parts of the Tejon would supply them in sufficiently large amount to counteract the low concentration in the Chico and Vaqueros. Some new grains would doubtless be supplied by attrition of the pebbles of the older conglomerates. The conclusion is reached that, while it is impossible to say whether or not detritus was supplied to the lower Pico basin from formations other than those occurring in the immediate region, if such detritus were supplied it was not of a sufficiently different character, or was not in sufficient quantity, to alter materially the composition of the Pico sandstones from the composition they would have had if the detritus were not supplied.

Clay.—The argillaceous beds of the Pico formation have been variously defined as clay, shale, claystone, mudstone, and siltstone; terms which are given a slightly different meaning by different authorities. In a strictly petrologic sense, the writer considers unlithified, clastic sediments whose grain size lies between 0.05 and 0.005 milimeters, *silt*; and its massive, lithified derivative *siltstone*. Unlithified, clastic sediment with grains smaller than 0.005 millimeters is considered *clay*; and its massive, lithified derivative *claystone*. When the lithified derivative of either silt or clay is not massive, but possesses a cleavage parallel to the bedding, without development of megascopic, secondary mica, it is considered *shale*. Most dry shale on being wetted retains its coherence, while dry clay or silt similarly treated slacks and falls apart. In the terms of this classification, the argillaceous beds of the lower Pico are clay and silt, and for the purpose of everything but laboratory analysis, when the material is not pure silt it is referred to as clay.

Clay is a very important constituent of the lower Pico, forming a greater proportion of some sections than of others because of lateral

variation. Dark gray, blue-gray, and black are its colors upon fresh exposure, but it weathers light gray or gray-buff. When freshly exposed it is moist and firm, but not hard; and after drying it becomes somewhat harder and more brittle. It is ordinarily well bedded, forming massive layers as much as 18 inches in thickness, and is commonly laminated. In texture it is generally slightly silty, and even sandy. Carbonaceous matter is profusely disseminated, giving it the gray color, and is in places concentrated into thin, discontinuous seams of lignite. Salt amygdules, similar to those in the upper Pico, occur locally, and a few inconspicuous particles of free sulphur and gypsum. Much of it is foramin'feral; and these and some other parts are slightly calcareous.

Since this clay occurs interbedded with conglomerate and sandstone, the constituents of which were probably derived largely from the Cretaceous, Eocene, Oligocene(?), and Miocene beds of the region, the land waste represented in the clays was probably derived from the same source, principally the shales.

COMPOSITION OF THE UPPER PICO

Clay.—The upper Pico is essentially an argillaceous member, the lower one-third of which is somewhat sandy (Fig. 12). The material is referred to the term *clay*, since only upon laboratory analysis is it apparent that the major proportion of it is silty in texture. Its lithology is on the whole uniform wherever the member is exposed in the Ventura quadrangle, although a few miles east of Canada Larga syncline, and on South Mountain, it contains intercalated sandstones and conglomerates, and loses its distinctive character.

The color of the upper Pico clay upon fresh fracture is blue-gray to black, due to finely disseminated carbonaceous matter. Weathered surfaces are gray-brown with ferric oxide. In different parts it is massive with conchoidal fracture, nodular, and shaly. Most parts of it can be seen with a hand lens to be of a silty texture, but the true proportions are not evident and clay seems predominant. Physical analyses by elutriation were made of four typical samples collected in Hall Canyon, and the fact was revealed that the so-called "clay" contains, on an average, less than 30 per cent of particles smaller than 0.005 millimeters. The results of the two most reliable analyses follow:

PHYSICAL ANALYSIS OF UPPER PICO CLAY, HALL CANYON

Sample I, 450 feet above base

	Per Cent
Silt and very fine sand	88.2
Clay and soluble salt	11.8

Sample II, 2,600 feet above base

Silt and very fine sand	74.3
Clay and soluble salt	25.7

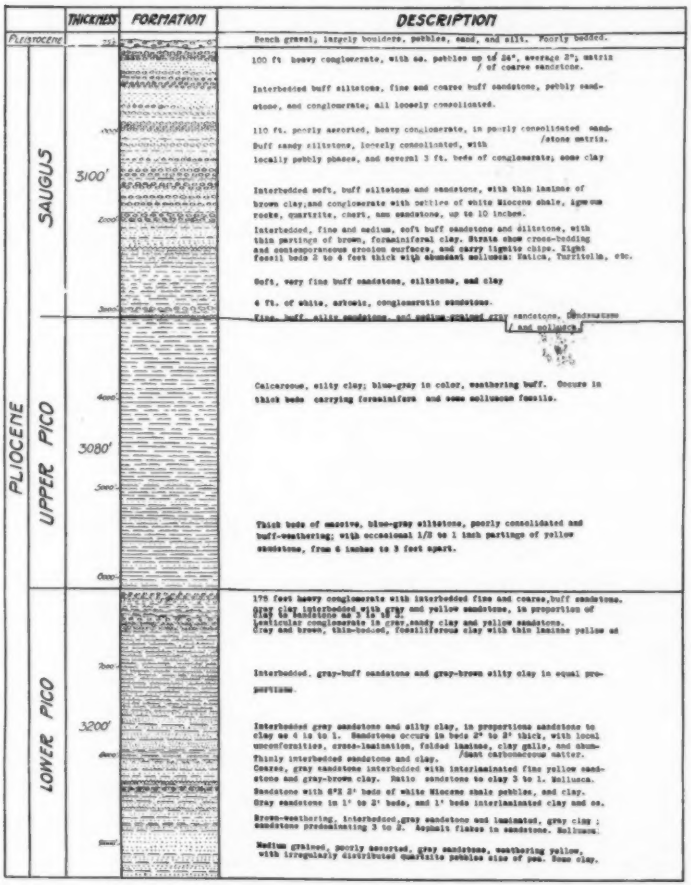
THICKNESS
FORMATION
DESCRIPTION
PLEISTOCENE
Bench gravel, largely boulders, pebbles, sand, and silt. Poorly bedded.
PLIOCENE
SAUGUS
3100'
100 ft heavy conglomerate, with so. pebbles up to 24", average 2"; matrix of coarse sandstone.
Interbedded buff siltstone, fine and coarse buff sandstone, pebbly sandstone, and conglomerate, all loosely consolidated.
110 ft. poorly assorted, heavy conglomerate, in poorly consolidated sandy matrix.
Buff sandy siltstone, loosely consolidated, with stone matrix.
locally pebbly phases, and several 3 ft. beds of conglomerate; some clay
Interbedded soft, buff siltstone and sandstone, with thin laminae of brown clay; and conglomerate with pebbles of white Miocene shale, igneous rocks, quartzite, chert, and sandstone, up to 10 inches.
Interbedded, fine and medium, soft buff sandstone and siltstone, with thin partings of brown, foraminiferal clay. Strata show cross-bedding and contemporaneous erosion surfaces, and carry lignite chips. Eight fossil beds 2 to 4 feet thick with abundant molluscs: Natica, Turritella, etc.
Soft, very fine buff sandstone, siltstone, and clay
4 ft. of white, arkosic, conglomeratic sandstone.
UPPER PICO
3080'
Calcareous, silty clay; blue-gray in color, weathering buff. Occurs in thick beds carrying foraminifera and some molluscan fossils.
Thick beds of massive, blue-gray siltstone, poorly consolidated and buff-weathering; with occasional 1/8 to 1 inch partings of yellow sandstone, from 6 inches to 3 feet apart.
LOWER PICO
3200'
175 feet heavy conglomerate with interbedded fine and coarse, buff sandstone.
Gray clay interbedded with gray and yellow sandstone, in proportion of clay to sandstone as 3 is to 2.
Lenticular conglomerate in gray, sandy clay and yellow sandstone.
Gray and brown, thin-bedded, fossiliferous clay with thin laminae yellow st
Interbedded, gray-buff sandstone and gray-brown silty clay in equal proportions.
Interbedded grey sandstone and silty clay, in proportions sandstone to clay as 4 is to 1. Sandstone occurs in beds 2' to 3' thick, with local unconformities, cross-lamination, folded laminae, clay galls, and abundant carbonaceous matter.
Thinly interbedded sandstone and clay.
Coarse, gray sandstone interbedded with interlaminated fine yellow sandstone and gray-brown clay. Ratio sandstone to clay 3 to 1. Molluscs.
Sandstone with 6"X 2' beds of white Miocene shale pebbles, and clay.
Gray sandstone in 1' to 2' beds, and 1' beds interlaminated clay and ss.
Brown-weathering, interbedded gray sandstone and laminated, gray clay; sandstone predominating 3 to 2. Asphalt flakes in sandstone. Molluscs.
Medium grained, poorly assorted, gray sandstone, weathering yellow, with irregularly distributed quartzite pebbles size of pea. Some clay.

FIG. 12.—Columnar section, Hall Canyon, south of anticline from cross-section *A-A'*.

The silt and sand occu ring with the clay consist of angular, flaky grains ranging from 0.005 to 0.10 millimeters in diameter, averaging 0.04 millimeters. Quartz, and to a less extent, feldspar (orthoclase, plagioclase, and microcline) are the most prominent minerals. Biotite, chlorite, and muscovite are commonly present in some quantity, and heavy minerals including hornblende, apatite, and zircon. Calcite is ordinarily present in the samples, and as the beds are fossiliferous, it is believed to be derived, for the most part, from shells. Many of the quartz and feldspar grains are partially stained with limonitic matter, and some beds contain small, limonitic concretions.

Sand.—The thin partings of fine sand, as a rule less than an inch thick, which occur from 4 inches to 3 feet apart in the lower third of the member, are yellow, and many are cross-laminated, ripple-marked, and somewhat lignitic. The sand is composed of the same constituents as the silt and very fine sand of the clay beds.

Volcanic ash.—Two thin beds of white volcanic ash occur in the upper Pico along the west side of Ventura River south of Canada del Diablo, at horizons 1,000 and 1,600 feet, respectively, above the base. The beds range from 1 to 6 inches thick, and persist the length of the outcrops, about 100 feet, but have been found nowhere else in the quadrangle. The composition of both beds is the same, the material being principally *rhyolitic glass* with an index of refraction between 1.49 and 1.50, occurring as minute shards and splinters. Some fine quartz and feldspar crystals, and possibly biotite, occur with it in small proportion.

Salt amygdules.—The salt occurring in the minute amygdules described earlier in this paper occurs typically in the upper Pico, as well as in the lower Pico. Surface waters leach it out of the clay and deposit it as a crust along creek courses. An analysis from Canada de Rodriguez showed the following constituents:

ANALYSIS OF SALT, CANADA DE RODRIGUEZ

	Per Cent
Na_2SO_4	49.28
$MgSO_4$	15.41
Water and impurities	35.31
	100.00

DIAGENESIS OF THE PICO SEDIMENTS

Cementation.—The poorly lithified sediments of the Pico formation are characteristically incompletely cemented. Very small proportions

of clay between the grains of sand in the sandstones and conglomerates form the most widespread binding material. This clay may be in part argillaceous material deposited with the coarser grains, and in part residue from the weathering of feldspar grains after deposition. The pelitic or argillaceous matter of the clay beds is probably cemented more by the compacting with slight recrystallization of the fine particles and drying of the colloidal matter, than by deposition of cement between the grains. Calcite and iron oxide are quite widespread in the formation, but are only locally concentrated sufficiently to serve as an effective cement.

Concretions.—Concretions are not prominent features of the Pico formation, but occur rather generally through it. In parts of the upper Pico clay small ferruginous concretions less than an inch in diameter are distributed through the beds. Larger concretions in the lower Pico sandstone have resulted from local cementation of the sand grains on both sides of a joint or bedding plane by limonite. These are rarely more than 2 feet long, and 4 or 5 inches thick at the center. Brown, calcareous concretions 2½ feet long and 8 or 10 inches thick occur along bedding planes in calcareous sandstone near the base of the Pico formation in the Santa Paula quadrangle, between Sulphur and Hammond canyons. Precipitation from vadose waters led to the formation of all the concretions mentioned.

Desalinification.—One of the normal processes of diagenesis is desalinification, the leaching-out of the residual salts left in the sediments by occluded sea water. This process is now operating in the Pico formation, as is shown by the salt crust along the margins of the creeks and springs at places in the formation.

CONCLUSIONS

ORIGIN OF DETRITAL MATERIAL

Lower Pico.—Detailed study of the Cretaceous, Eocene, Oligocene(?), and Miocene formations of the Ventura quadrangle and adjacent region, followed by a detailed study of the pebbles forming the lower Pico conglomerates, shows conclusively that they were derived from the older formations named. The petrology of the lower Pico sandstones, supported by the facts indicated by the conglomerates, justifies the conclusion that the sandstones and shales in these older formations, and to a certain extent the pebbles in the older conglomerates, were the principal sources of the lower Pico sands and clays.

Upper Pico.—The thin sand partings of the lower part of the upper Pico are petrologically similar to the sandstones of the lower Pico,

and the clays of the upper Pico are lithologically similar to the clays of the lower Pico. Because of these similarities, and the close stratigraphic relations of the two members, it is considered probable that their detrital materials had a common source. The rhyolitic tuff in the upper Pico is of volcanic origin.

CONDITIONS OF ORIGIN

The feldspar grains in the pre-Pico feldspathic sandstones of the region range in degree of decomposition from clear and unchanged to cloudy and considerably sericitized, the prevailing condition being one of moderate to considerable decomposition. The sandstones of the Pico formation contain a prominent proportion of feldspar grains, in about the same state of decomposition as the feldspar grains of the older formations. This presence of a considerable proportion of readily decomposable detrital grains in the Pico sandstones indicates that the weathering of the surface of the old land-mass was predominantly of the mechanical disintegration type, and that chemical decomposition played a less important part.

The clays of the Pico formation are characteristically carbonaceous, and the sandstones in certain zones carry chips and shreds of lignite, and are gray before weathering, from the presence of finely-divided carbonaceous matter. It is possible that some of this may be of marine origin representing debris from seaweed and kelp, great beds of which fringe the present coast (Fig. 5); otherwise, it represents vegetal matter washed into the basin by streams, and indicates humidity of climate. The fauna of the Pico formation indicates a temperate climate.

A hypothetical environment which satisfies the evidence of the sediments of the lower Pico is a high region of topographic youth relatively near the basin of deposition. The climate is temperate, with intermittent rainfall enough to promote the growth of vegetation in the valleys, but the mountain sides are steep and support only a sparse growth. The sandstones, shales, and conglomerates are soft and readily erodible, and are rapidly reduced by a combination of the elements; and the debris is transported by short, heavily loaded streams to the waters of the basin of deposition.

The development of the upper Pico clay member in parts of the Ventura and Santa Paula quadrangles was induced by a change of conditions. Since the clay member cannot be distinguished lithologically on South Mountain, or east of Canada Larga, the change was not of a regional nature as a change of climate would be; but was more

likely a local topographic change such as the reduction of the drainage areas of the streams flowing into this part of the basin to topographic maturity with a consequent widespread development of vegetation and greatly reduced transporting power of the streams.

CONDITIONS OF DEPOSITION

Lower Pico.—The presence of marine fossils throughout the Pico formation shows that the sediments were laid down in a marine basin. During lower Pico time the waters were prevailingly shallow and agitated by waves and currents, giving rise to coarse sediments in beds with such depositional features as cross-bedding, ripplemarks, cut-and-fill structures, and pudding-balls. The bottom on which deposition took place was uneven and sloping. Sand bars moved back and forth across it, and currents cut into the bottom at some places and re-deposited the sediment at others. Small slides and slumps occurred where the slope became too steep for muds to rest. In different parts of the basin, relatively adjacent to each other, materials of different character and in different thicknesses were deposited simultaneously, giving rise to lateral variation and lenticularity. Occasionally, small areas of the bottom were exposed as mud flats, giving rise to mud contraction cracks and subsequent clay galls in the sandy sediments.

The strength of the transporting agents and the material transported varies from time to time at the same point, leading to the deposition of conglomerate, sandstone, and clay in thin, alternating layers. In some parts of the formation thick series of alternating beds of sandstone and clay, maintaining a constant thickness of a foot or less, indicate a rhythmic recurrence of similar conditions at the same point. Each such period of similar conditions may have constituted a sort of climatic season, the sandstone beds wet seasons, with the streams on land bearing coarse detritus, the clay beds dry seasons, with the streams on land bearing only the finer waste. Some of the sandstone beds have a gradation in texture from coarse at the base to fine at the top, showing the gradual decline in size of the material borne by the streams and currents as the time since the height of the last wet season increased, and further supporting the hypothesis of recurring climatic periods controlling deposition.

Deposition took place at a rapid rate, burying readily reduced pebbles of shale before wave and current action could break them up, and covering mud flows before the material could be re-worked and assorted. In the zones suggesting control of climatic seasons, some

of the individual beds are 2 feet thick, though the average is about 10 inches to 1 foot thick. The deposition of such a thickness in a season, even though it is impossible to compare the length of a Pliocene season to one of the present, indicates the rapidity with which deposition took place. As the beds were deposited, the bottom on which they were laid gradually subsided, so that 9,300 feet of sediments were laid down under shallow-water conditions almost throughout. The adjacent land-mass was elevated proportionately, so that coarse detritus was supplied to the basin of deposition from time to time during the epoch. This feature of recurrent depression of the basin of deposition so that such an enormous thickness of shoal-water sediments might accumulate, and of recurrent uplift of the adjacent land-mass so that boulders, gravel, and coarse sand might be furnished by erosion to the streams carrying the detritus, is worthy of considerable emphasis.

Upper Pico.—The upper Pico epoch is characterized in the Ventura quadrangle by remarkably uniform conditions of supply and deposition. A few miles east and southeast in the Santa Paula quadrangle this uniformity did not exist, and there is a sharp transition along the strike of the beds from silty clay to conglomerate, sandstone, and clay. The evidence afforded by the outcrops of upper Pico is insufficient to establish the member as being either a deep-water, silty phase of the Pico formation, or as owing its fine texture to physiographic conditions on the adjacent land-mass. In view of the fact that the strand line maintained a general east and west trend during lower Pico time, the writer is inclined to accept the hypothesis that the clay member in the Ventura quadrangle represents relatively near-shore deposition adjacent to a land-mass of topographic maturity or old age, from which the streams bore only the finer products of land waste, barriers preventing off-shore currents from sweeping coarser debris in from other places along the coast.

GENESIS OF A SANDSTONE DYKE AS INDICATED BY HEAVY MINERALS[1]

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ABSTRACT

A small tar-impregnated dyke cuts Miocene shale just east of the old Newport Beach field, Orange County, California. Heavy mineral analyses show that the material of the dyke corresponds with underlying Miocene sand rather than with overlying younger formations. The Miocene in the area is characterized by a lack of green hornblende and an exceptionally large amount of glaucophane. The reverse is true of the Pleistocene. An earthquake probably formed a fracture into which was forced water-soaked sand from a lower formation. The oil and tar which occur in the dyke and the overlying Pleistocene beds probably entered subsequently to the sand-filling of the dyke.

Some interesting data relative to the formation of a sandstone dyke were obtained recently in connection with a study of the heavy mineral content in the sediments along the eastern border of the Los Angeles basin.

This sandstone dyke is located near Newport Beach, Orange County, California, on the north side of the coast highway to Laguna Beach, about ¾ mile east of the old Newport Beach field.

At this place a steep bank about 50 feet higher than the road, exposes beds of Miocene brown shale dipping 8° W., overlain unconformably by flat-lying Pleistocene terrace sands. The unconformity is indicated by the very evident angular discordance between these two formations, and by the presence of a coarse sandy conglomerate at the base of the terrace deposits that contains brown shale boulders as large as a foot in diameter. *Pholas* borings occur in the shale boulders, and extend downward into the underlying brown shale. The fossil organism itself may be observed in place at the bottom of some of the borings.

The sandstone dyke, as may be seen in the accompanying photograph (Fig. 1), cuts the brown shale in practically a vertical attitude. It ranges from eight to twelve inches in width, but the upper part of the

[1]Read before the Pacific Section of the Association, at the Los Angeles meeting, October 27, 1927. Manuscript received by the editor, December 30, 1927.

outcrop exhibits some irregularities and slight offsets, due possibly to minor shearing along bedding planes after the dyke was formed.

The dyke has been exposed by a tunnel for a distance of 20 feet, where it was found to retain the same width and vertical attitude as

FIG. 1.—Sandstone dyke cutting Miocene brown shale.

were noted at the surface. This would seem to indicate that the dyke probably extends for a considerable distance, but just how far would be impossible to determine.

It is also interesting to note that both the dyke and the overlying terrace sands for a distance of 300 yards or more from the point of contact with it, are impregnated with tar. The terrace sands, however, become progressively less strongly saturated with oil as the distance from the dyke increases, for the tar impregnations finally feather out into material which apparently has never contained oil. Even the sand

filling the *Pholas* borings which extend downward into the brown shale, has been impregnated. The brown shale, however, exhibits no oil stains whatsoever.

At the time this sandstone dyke was first observed in the field, a suite of outcrop samples was being obtained from the Newport Beach area for heavy mineral analyses. Merely as a matter of interest, the collection was extended to include samples from the dyke with the hope that its origin would be indicated by the study of heavy minerals. Material was also taken from the overlying tar sands, special effort being exercised to obtain one sample from a point as close to the contact of the dyke and tar sand as possible.

STRATIGRAPHY IN VICINITY OF NEWPORT BEACH

In order to gain a more complete idea of the conditions here, and to understand the significance of the mineral analyses, a brief statement of the stratigraphy of this area is included.

The tar-impregnated Pleistocene sands form the base of the most recent terrace deposit in the Newport Beach district. It is the equivalent of the lowest terrace found in the adjacent San Joaquin Hills, and probably is a part of the warped and tilted terrace surface along the line of topographic highs extending from Huntington Beach to Inglewood. The Pleistocene terrace material is underlain on the north and west by successively lower formations of the Pliocene.

The Miocene section as exposed from top to bottom at Newport Beach may be generalized as follows:

MIOCENE SECTION AT NEWPORT BEACH

1	Brown shale..... 600-800 feet	Fish scales, sponge spicules, no intact diatoms or foraminifers. Thin sand partings ⅛-¼ inch thick.
2	Soft white laminated shale.... 800-1,000 feet	Miocene diatoms and foraminifers. Few thin sand partings as above. Near base of shale a lenticular tar sand 15 feet thick, 100 feet wide.
3	Brittle opaline shale..... 500-700 feet	A few tar-impregnated cracks.
4	Hard indurated sand.....	Numerous basalt grains.
5	Basalt breccias.....	Intruded andesites.

The sandstone dyke cuts the brown shale member at the uppermost part of the section, which we note contains no sand phases, except very thin partings. Samples were collected, however, from two of the sand

partings and from the tar-impregnated sand body near the base of the white, laminated shale. Pliocene samples were taken for additional comparison.

HEAVY MINERAL ANALYSES

Prior to a study of the samples collected from the Newport Beach area, a mineral break had been established between the Pliocene and Miocene formations on the east side of the basin.

The Pliocene samples were found characteristically to yield a concentrate containing green hornblende as the dominant, or flood mineral. In many samples it amounted to as much as 70 per cent of the total heavy mineral aggregate. Other minerals, such as epidote, garnet, titanite, zircon, and non-magnetic opaques, were also present, but in many samples these, even when considered as a group, were subordinate in amounts to the green hornblende.

The Miocene produced a concentrate consisting of the more resistant types, namely, garnet, titanite, zircon, and opaques. Green hornblende was entirely absent. Epidote, although present in some samples in considerable amounts, was missing in others, or found in amounts not more than 2 or 3 per cent of the total heavy concentrate.

Although a few scattered grains of tourmaline and glaucophane were found here and there in the Pliocene, they were much more plentiful in the Miocene. Only a few samples showed as much as 1 or 2 per cent of these minerals, and they may therefore be classed as incidental accessories. In themselves, they are not diagnostic, yet any concentration of one, or both of them, is more indicative of the Miocene than of the Pliocene.

This earlier work had thus shown the existence of mineralogic differences between the Pliocene and Miocene formations, which might be equally applicable in the Newport Beach district.

In examining the samples from this area, it was found that the same mineral break existed. Green hornblende was plentiful in the Pliocene and Pleistocene, but was absent in the Miocene. Epidote in considerable amounts was found to be common to both formations. In addition the Miocene contained an exceptionally large amount of glaucophane.

Having thus established the existence of a mineral discontinuity which would permit a differentiation between material from the Miocene and from the Pliocene, it was possible to use this information as an index to determine the nature of the sand filling the dyke.

The heavy mineral content of the dyke is as follows:

	Per Cent
Epidote	40
Garnet	20
Titanite	20
Zircon	3
Glaucophane	2
Opaques	15

Notice that green hornblende is absent, and that there is an exceptional concentration of glaucophane. As this assemblage is typical of a Miocene sand, it fixes the age of the material filling the dyke.

The overlying Pleistocene tar sand yielded a concentrate as follows:

	Per Cent
Green hornblende	60
Epidote	20
Garnet	4
Titanite	10
Zircon	1
Opaques	15

The green hornblende content and the absence of either tourmaline or glaucophane are the important features of this concentrate. These mineral analyses indicate that the Miocene sands contain no green hornblende, but do carry much glaucophane or tourmaline, whereas a reverse condition exists in the younger formations.

ORIGIN OF THE DYKE

There are two ways in which this particular sandstone dyke could have been formed: (1) by the development and maintenance of a fissure in the bedrock, which was subsequently filled with sand that was being drifted by near-shore currents, or (2) during a severe earthquake shock, or while the beds were being warped or folded, a fracture could have been developed, into which soft, incoherent, and perhaps water-soaked sand was forced, or injected, from some source lower in the section, by virtue of the compressional forces which were operative during such a condition of exceptional earth stresses.

That mobile substances are subject to re-distribution when acted on by sufficient pressures is indicated by the soft, heaving sands which are encountered in oil-well drilling. Furthermore, an instance is known where small surface rifts, produced during an earthquake, were filled by soft, water-soaked sand from beneath.

It is evident from the mineral analyses that the first method will not explain the origin of this dyke. Had it been filled by an influx of

Pliocene or Pleistocene material into an open fissure the sand in the dyke would necessarily contain much green hornblende. In addition, had such a condition prevailed at the close of Miocene deposition it would still be impossible to account for it in this manner. It has already been pointed out that the brown shale member of the Miocene is barren of sands, except as thin partings; therefore it is reasonable to conclude that sand particles were not being contributed in sufficient amounts at this time to account for the complete filling of a fissure 8 to 12 inches thick.

The only source of sand in large enough quantities, yet having the necessary mineral qualifications, to account for the filling of this dyke, is to be found in the lower part of the laminated white shale, immediately below the brown shale member in which the dyke is known to occur. One lenticular body of tar-impregnated sand has already been noticed at this position in the section.

With the evidence at hand it seems probable that this dyke was formed as a result of exceptional earth stresses causing a fracture into which soft, mobile sand from some position lower in the section was injected under considerable pressure, much in the same manner as an igneous intrusion. The sand was forced upward along this fissure for considerably more than 1,000 feet. Such a genesis will account for the sharp and distinct contact between the brown shale and the dyke, and at the same time fill the dyke with a sand capable of yielding the heavy mineral aggregate that was obtained from it.

The question may arise as to whether the sand in the dyke was saturated with oil at the time of injection, or whether it became oil-soaked subsequent to its formation. This matter is dependent upon the age of the dyke. It is not possible to fix definitely the time at which this injection of sand took place. It must necessarily antedate the deposition of the Pleistocene terrace sands. If the injection had occurred under the present terrace cover, sufficient sand from the dyke would have been forced into the soft overlying material actually to produce a dilution of a high green hornblende assemblage, by an accession of hornblende-free sand from the dyke. The analysis of the sand collected from a point as close to the contact of dyke and terrace sand as possible, showed a green hornblende content identical with the remainder of the samples from the terrace.

This would indicate that the dyke had been formed prior to the deposition of the terrace beds, and that any excess sand had been reworked in the formation of the Pleistocene covering.

It might be well to note again that *Pholas* borings containing the organisms themselves were found within a few feet of the dyke. The presence of these fossils precludes the possibility of an oil-soaked sand being a filler for the dyke. Had such been the case the dyke would necessarily have remained an active seep until after the Pleistocene beds were deposited, in order to account for the tar impregnation now to be found in them.

In this event it is somewhat difficult to imagine marine organisms living within the area of a brea deposit, particularly when the sand filling their borings has been impregnated with tar as well.

The most likely explanation is that the dyke was formed by a soft, water-soaked, highly mobile sand. The tar impregnations in the dyke and Pleistocene terrace sands occurred subsequent to the formation of the terrace covering, and indicate how recently oil migration has taken place within formations situated in the Los Angeles basin.

GEOLOGICAL NOTES

SOME TESTS ON CEMENT AND CEMENT ACCELERATORS

The feasibility of using accelerators with cement in oil and gas wells has been a matter of varied opinion among operators. The figures given in this report are the result of considerable time and effort spent in an attempt to secure reliable data. Time and pressure are the only variables used and these are considered adequate for all practical purposes. Three-inch test pieces of cement, having a minimum cross-section area of one square inch, were made in gang molds, and tensile strengths noted as soon as possible after removing from the molds. The tests for strength were made by the Barrow-Agee laboratories of Shreveport, Louisiana.

Referring to the tabulation, the "No-pressure" test pieces were set under about two inches of water. A pressure chamber was constructed for the purpose of maintaining water pressures on the samples equivalent to submergence pressures in wells. Constant pressures were not secured by this method, due to "sweating" of water through the welds and threads. Thread compounds and mud were tried without success, the pressure dropping at least 25 per cent overnight. The cement did not do well under the varying pressure. A certain amount of air was dissolved in the water and its contraction and expansion in the cement no doubt were responsible. This condition is assumed to represent a slight amount of agitation. A constant pressure was secured by submerging the samples 1,650 feet under water and mud in an idle well. The cement was held in the molds by binding strips of tin over them, and they were found to be full size when removed for testing.

Five well-known accelerators were used in the tests with a good grade of Portland cement. Straight Portland cement was included for comparison and also a highly aluminous cement was used without adding accelerator. Where accelerator was used it was added according to directions. The cement in each case was mixed with water or with water and accelerator in the proportions of 35 pounds of liquid to a sack of cement. This is a somewhat stiffer mixture than is usually

pumped, but this stiffer slurry was considered advisable for better retention in the molds while submerging in water. The usual pumping mixture, when the operator tries to use a stiff mix, is between 40 and 45

CEMENT

TENSILE STRENGTH, POUNDS PER SQUARE INCH

	Submerged 2 In. Water No Pressure				*Variable Pressure Cylinder* 250 Lb. to 1,200 Lb.		*Variable Pressure Cylinder* 250 Lb. to 700 Lb.		Submerged in Well 1,630 Ft. Under Water and Mud About 800 Lb. per Sq. In.				
	2 Days	4 Days	7 Days	10 Days	10 Days	10 Days	10 Days	2 Days	5 Days	7 Days	10 Days	28 Days
Average Test of 5 Accelerators	229	298	321	422	150	192	173	224	256	332	340	499
Straight Portland Cement	170	285	365	255	190	240	145	365	520	450	524	565
Highly Aluminous Cement—No Accelerator	610	487	360	430	376	657	360	716	685	670	570	644

pounds of water per sack of cement. The "No pressure" and "Pressure cylinder" samples were mixed with Shreveport city water as it was during the fall of 1925. It was in poor condition at that time on account of low water. The tests in the well were made during December, 1925, and January, 1926, and the cement was mixed with puddle rain water. As shown in the table, distilled water was used in one case and 214° F. was applied to Portland and aluminous cement for 10 days after setting 10 days under variable pressure.

Some of the figures shown in the table are the average of as many as three samples. There is some irregularity shown in the comparison of straight cement and that mixed with accelerators. The tests indicate that there is an advantage in using one of these five accelerators for surface work, but that they may not serve the same purpose when under considerable pressure. It is realized that the experimental error is rather large for cement. Attention is called to the necessity of being sure that cement is of suitable quality, and has not deteriorated too much with age. Cement for use in wells should be tested at least as carefully as for surface construction work. If the oil and gas operators buy cement and use it without testing it, there is the possibility that they will be using cement of poor quality or even some that has been rejected by building contractors. As far as the writers are aware, these are the first tests to be made on cement and accelerators under pressure. The "No-pressure" tests agree with many other sets of tests in showing a strength advantage when accelerator is used, but the reverse is indicated when pressure is applied. The experiments were conducted under the Minerals Division of the Department of Conservation of Louisiana. The writers are no longer connected with that organization. These limited tests are considered merely indicative and are published with the hope of encouraging others to make further tests under pressure, and publish results. This is a very important subject to the oil operator and deserves consideration. It would be of great interest to compare the initial and final sets of straight cement and accelerator mixtures under pressure and no pressure.

H. W. Bell and M. W. Grimm

Chicago, Illinois
and
Shreveport, Louisiana
January, 1928

REVIEWS AND NEW PUBLICATIONS

RECENT PUBLICATIONS

GENERAL

"Geophysical Methods of Prospecting," by A. S. Eve and D. A. Keyes. *Technical Paper 420, U. S. Bureau of Mines*, Washington, D. C. Free.

The Geological Review, Vol. 1, No. 1, February, 1928. Abstracts and reviews of publications on petroleum geology, edited and published monthly by Esther S. Johnson, Box 2345, Denver, Colorado. Annual subscription upon application.

CALIFORNIA

"Properties of California Crude Oils, III; Additional Analyses," by A. J. Kraemer. *Report of Investigations Serial No. 2846, U. S. Bureau of Mines*, Washington, D. C. Free.

ILLINOIS

"Stratigraphy and Geological Structure of Northern Illinois with Special Reference to Underground Water Supplies," by F. T. Thwaites. *State Geological Survey*, Urbana, Illinois.

"The Media Anticline," by A. H. Bell and L. E. Workman. *State Geological Survey*, Urbana, Illinois. Price, $0.25.

OKLAHOMA

The following new reports may be obtained from the Oklahoma State Geological Survey, Norman, Oklahoma:

"Oil and Gas Geology of Atoka, Pushmataha, McCurtain, Bryan, and Choctaw Counties," by C. W. Honess. *Bulletin 40-R*. Price, $0.30.

"Oil and Gas Geology of Pontotoc County," by R. A. Conkling. *Bulletin 40-S*. Price, $0.30.

"Oil and Gas Geology of Washington County," by Everett Carpenter. *Bulletin 40-V*. Price, $0.30.

"Oil and Gas Geology of McIntosh County," by R. W. Clark. *Bulletin 40-W*. Price, $0.30.

"Fossiliferous Boulders in the Ouachita 'Caney' Shale and the Age of the Shale Containing Them," by E. O. Ulrich. *Bulletin 45*. Price, $0.30.

"Age Relations of the Carboniferous Rocks of the Ouachita Mountains of Oklahoma and Arkansas," by Hugh D. Miser and C. W. Honess. *Bulletin 44*. Price, $0.30.

TEXAS

"Analyses of Crude Oils from the West Texas District," by A. J. Kraemer, Peter Grandone, and C. S. Luce. *Report of Investigations Serial No. 2849, U. S. Bureau of Mines*, Washington, D. C. Free.

"Igneous Rocks of the Balcones Fault Region of Texas," by J. T. Lonsdale. *University of Texas Bulletin 2744, Bureau of Economic Geology*, Austin, 1927. 178 pp., 29 illus. Price, $0.75.

GERMANY

Die Verwässerung von Erdölfeldern, by Walter Kauenhowen. Julius Springer, Berlin, 1928. 80 pp., 54 figs. Price R M, 7.50.

VENEZUELA

The Geology of Venezuela and Trinidad, by Ralph A. Liddle. Published by J. P. MacGowan, Box 1,007, Fort Worth, Texas, 1928. xlii + 552 pp. 6 x 9 inches, 169 half-tones and 24 sections and maps. Cloth. Price, postpaid, $7.50.

THE ASSOCIATION LIBRARY

Headquarters acknowledges library accessions:

VIRGINIA

From Albert W. Giles:
Oil and Gas Possibilities of Virginia

THE ASSOCIATION ROUND TABLE

EXECUTIVE COMMITTEE AT TULSA, JANUARY 26, 1928

The Executive Committee met at Association headquarters, 504 Tulsa Building, Tulsa, Oklahoma, on January 26, 1928. Members present were G. C. Gester, president, Luther H. White, vice-president, and John L. Rich, editor. Election of J. B. Burnett of Maracaibo, Venezuela, as the representative of South America on the general business committee, was approved.

In accordance with the authorization of the Association in annual business meeting of March 25, 1927, the following amendment was declared to be a part of the by-laws of the Association:

SEC. 5. District representatives to act as a council for the Association and as an advisory board to the executive committee shall be elected by the members of the several districts. Districts are to be designated by the executive committee. The number of each district's representatives on the general business committee shall be determined by the executive committee according to the number of active members residing in each district. Should any district fail to elect a representative, the president shall appoint such a representative at least thirty days before the annual meeting. The term of office of each representative shall commence with the first annual business meeting following his election, and shall be three years, excepting that one-third of those elected the first year of the adoption of this amendment shall serve for one year only, and one-third shall serve for two years only, thus providing that one-third of the representatives shall retire each year. The district representatives, together with the executive committee, shall constitute the general business committee which shall convene at the time of the annual meeting of the Association for the purpose of considering any business which may properly come before the Association, and of making recommendations for action by the Association. The chairman of the general business committee shall be appointed by the president at least sixty days before the annual meeting.

In accordance with the resolution passed at the annual business meeting of the Association, March 15, 1919 (See *Bulletin*, Vol. III, 1920, p. 18), the fiscal year of the Association was declared established to correspond with the calendar year. The audit of the Association books as of December 31, 1927, is therefore presented herewith.

REPORT OF THE TREASURER

AUDITOR'S STATEMENT

1715 East Thirteenth St.,
Tulsa, Oklahoma,
February 6, 1928.

MR. J. P. D. HULL, Business Manager,
American Association of Petroleum Geologists,
Tulsa, Oklahoma.

DEAR SIR:

In compliance with your request I have audited the accounts of the American Association of Petroleum Geologists for the period March 10, 1927, to December 31, 1927, and submit herewith a condensed statement showing the condition at December 31, 1927, and schedules of cash receipts and cash disbursements for the general fund and publication fund for the period, also schedules of cash and securities in each fund at the end of the period.

The cash on hand and in banks was verified and reconciled with the books, a statement of which is submitted with this report, the securities were counted and inspected and found to be the same as at the last audit, with the exception of the Wyoming farm loan, which was collected and deposited in the savings account at the National Bank of Commerce, October 25, 1927.

The books have been accurately kept, and I thank you and Miss Whalen for the courtesy and assistance extended during the audit.

I certify that, in my opinion, the statement and schedules submitted with this report present the true condition of the Association at December 31, 1927.

Yours very truly,

(*Signed*) W. O. THOMPSON,
Certified Public Accountant.

STATEMENT, DECEMBER 31, 1927

GENERAL FUND:			
March 10, 1927	Cash and securities on hand (Auditor's Report)		$29,810.54
	Cash received for period (Schedule 1)		23,860.56
	Amount to be accounted for		$53,671.10
Deduct:			
	Disbursements for period (Schedule 2)		26,413.76
	Surplus in General Fund (Schedule 3)		$27,257.34
PUBLICATION FUND:			
	Receipts for period (Schedule 4)	$4,325.27	
Deduct:			
	Disbursements for period (Schedule 4)	200.55	
	Surplus in Publication Fund (Schedule 5)		4,124.72
	TOTAL SURPLUS		$31,382.06

SCHEDULE 1

CASH RECEIPTS FOR GENERAL FUND
MARCH 10, 1927, TO DECEMBER 31, 1927

MEMBERSHIP DUES:		
Associate dues	$3,362.00	
Active membership dues	9,408.75	
Total membership dues		$12,770.75
FROM BULLETIN:		
Subscriptions	$2,539.30	
Sale bound copies	1,897.30	
Sale of index	620.40	
Sale back numbers	1,675.83	
Advertising	2,333.55	
Separates	52.20	
Total receipts from Bulletin		9,118.58
SALT DOME VOLUME		1,083.53
OTHER:		
Interest earned on investments		751.35
Miscellaneous		136.35
TOTAL RECEIPTS FOR PERIOD PER STATEMENT		$23,860.56

SCHEDULE 2

CASH DISBURSEMENTS FROM GENERAL FUND
MARCH 10, 1927, TO DECEMBER 31, 1927

CHICAGO EDITORIAL SECRETARY, SALARY AND EXPENSE		$2,027.27
PRINTING:		
Printing Volume 11 No. 3	$1,382.16	
11 No. 4	915.63	
11 No. 5	1,131.82	
11 No. 6	1,051.89	
11 No. 7	1,283.18	
11 No. 8	1,141.55	
11 No. 9	1,097.57	
11 No. 10	1,058.94	
11 No. 11	1,128.00	
Total printing regular issues		10,190.74
OTHER EXPENSE:		
Printing Index	$940.65	
Printing separates	512.11	
Stencil corrections and mailing	923.16	
Cloth binding	348.55	
Engraving	74.23	
Miscellaneous	73.00	
Total other expense		2,871.70
Total publication expense		$15,089.71
GENERAL OFFICE EXPENSE:		
Manager's salary	$6,250.00	
Clerical salaries	2,464.50	
Printing	556.81	
Postage	492.90	
Office furniture and fixtures	440.23	
Supplies	194.00	
Exchange and refunds	106.10	
Telegraph and telephone	194.96	
Freight and drayage	290.77	
Executive expense	57.86	
Traveling expense	67.00	
Convention expense	5.50	
Miscellaneous	203.42	
Total office expense		11,324.05
TOTAL DISBURSEMENTS PER STATEMENT		$26,413.76

SCHEDULE 3

CASH AND INVESTMENTS, GENERAL FUND
DECEMBER 31, 1927

Cash in National Bank of Commerce (Principal Account)		$9,212.18
Cash in National Bank of Commerce (Petty Cash Account)		304.28
Cash in National Bank of Commerce (Savings Account)		1,140.88
Total Cash		$10,657.34
INTEREST-BEARING BONDS AND SECURITIES:		
Anaconda Copper Mining Co. (6%)	$1,000.00	
California Nevada Electric Co. (5%)	6,000.00	
Pondera County Refunding (5½%)	1,000.00	
Imperial Japanese Government (6½%)	500.00	
St. Louis and San Francisco Ry. (6%)	500.00	
United States Rubber Co. (5%)	1,000.00	
Hardin County Texas Road Bond (5%)	1,000.00	
Northern States Power Co. (6%)	1,500.00	
United States Treasury Certificates (Par $5,000)	4,100.00	
TOTAL INVESTMENTS		16,600.00
TOTAL SURPLUS, GENERAL FUND PER STATEMENT		$27,257.34

SCHEDULE 4

CASH RECEIPTS AND DISBURSEMENTS FOR PUBLICATION FUND
MARCH 10, 1927, TO DECEMBER 31, 1927

CASH RECEIPTS:	
New York Committee	$4,114.84
Interest New York	6.63
Sale of Continental Drift	203.80
Total receipts per statement	$4,325.27
CASH DISBURSEMENTS:	
Expense on Continental Drift	$ 200.55
TOTAL SURPLUS, PUBLICATION FUND	$4,124.72

SCHEDULE 5

CASH AND INVESTMENTS, PUBLICATION FUND
DECEMBER 31, 1927

Cash in Tulsa National Bank		$214.29
Cash in National Bank of Commerce		105.00
Cash on hand		56.80
Total cash		$376.09
INVESTMENTS:		
Morris Plan Co. 5% saving certificates	$3,700.00	
Morris Plan Co. 5% thrift coupons	48.63	
Total investments		3,748.63
TOTAL SURPLUS, PUBLICATION FUND		$4,124.72

BANK RECONCILIATIONS DECEMBER 31, 1927

NATIONAL BANK OF COMMERCE:			
Principal account:			
Dec. 31, Balance as per bank statement			$10,588.43
Less checks outstanding:			
188 J. P. D. Hull		$625.00	
189 Anna D. Whalen		150.00	
190 Margaret Skelton		100.00	
191 Petty Cash		300.00	
192 University of Chicago Press		96.25	1,271.25
Balance as per books			$9,317.18
Petty cash account:			
Dec. 31, Balance as per bank statement		$ 13.78	
Add: Check No. 191 dated Dec. 31 against principal account deposited in petty cash account Jan. 4, 1928		300.00	
Total		$313.78	
Less checks outstanding:			
10 Jas. U. Douglas	$2.00		
84 Oliver D. Boggs	2.00		
191 Alex W. McCoy	.50		
192 A. I. Levorsen	4.00		
195 K. C. Heald	.50		
196 John H. Wilson	.50	9.50	
Balance as per books			304.28

Savings Account:	
Dec. 31, Balance as per bank statement	1,140.88
Total in National Bank of Commerce as per books	$10,762.34
TULSA NATIONAL BANK:	
Dec. 31, Balance as per bank statement	214.29
Total cash in banks per books	$10,976.63
Dec. 31, Cash in office	56.80
TOTAL CASH AS PER BOOKS	$11,033.43

SCHEDULE OF FURNITURE AND FIXTURES DECEMBER 31, 1927

1927

March 10	Furniture & fixtures (Auditor's report)	$749.02
April 5	1 K D B 6415 Kardex cabinet	114.50
August 1	One eight-inch fan	6.85
Oct. 31	Two sections steel shelving	25.98
	Four sections steel shelving	66.80
	Linoleum for office floor	226.10
TOTAL		$1,189.25

DAVID DONOGHUE,
Treasurer.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to J. P. D. Hull, Business Manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each applicant.)

FOR ACTIVE MEMBERSHIP

Eric K. Craig, Los Angeles, Calif.
Frank S. Hudson, E. F. Davis, Roy R. Morse

Edmond A. L. Gevaerts, Villa Hermosa, Tabasco, Mexico
D. Trumpy, Alfred P. Frey, G. F. Kaufmann

Willem N. Kuiper, Puerto Mexico, Ver., Mexico
D. Trumpy, Alfred P. Frey, G. F. Kaufmann

Donald J. Munroe, Maracaibo, Venezuela
Bond Coleman, R. L. Marston, Fred H. Kay

Dimitri Muskhetov, Leningrad, Russia
Roswell H. Johnson, Ransom E. Somers, I. Tolmachoff

Ben H. Parker, Tulsa, Okla.
Glen M. Ruby, Ross L. Heaton, A. E. Brainerd

William M. Rau, Bakersfield, Calif.
Art R. May, Roy R. Morse, E. F. Davis

John N. Strigeoff, Moscow, Russia
I. P. Tolmachoff, Roswell H. Johnson, R. E. Somers

Charles L. Thompson, Eastland, Texas
Wilson B. Emery, E. B. Emrick, Charles T. Lupton

William P. Winham, Bakersfield, Calif.
Henry J. Hawley, S. H. Gester, George M. Cunningham

FOR ASSOCIATE MEMBERSHIP

Ronald L. Bartle, Tulsa, Okla.
H. W. Peabody, Robert H. Dott, A. L. Beekly

C. Lothrop Bartlett, Dallas, Tex.
S. H. Williston, D. M. Collingwood, James A. Waters

Hugh Dickson, Tulsa, Okla.
R. A. Birk, Dollie Radler, Sidney Powers

Victor E. Ekholm, Fort Worth, Texas
Claude F. Dally, Roy A. Reynolds, George C. Matson

Harry B. Fields, Iowa City, Iowa
A. C. Trowbridge, Allen C. Tester, Gail F. Moulton

Alvin J. Freie, Waverly, Iowa
A. C. Trowbridge, Allen C. Tester, Gail F. Moulton

Victor G. Hill, Wewoka, Okla.
Lewis G. Mosburg, Raymond C. Moore, S. S. Price

Lloyd R. Manning, Fort Worth, Tex.
H. F. Sackett, Leon J. Pepperberg, R. van A. Mills

John H. Nelimark, Tulsa, Okla.
G. C. Siverson, Darsie A. Green, A. I. Levorsen
Katherine Van Winkle Palmer, Ithaca, N. Y.
C. M. Nevin, H. Ries, Edwin A. Filmer
Robert D. Patterson, Bakersfield, Calif.
Art R. May, E. F. Davis, John G. Burtt
Fred E. Roth, Jr., Amarillo, Tex.
C. Max Bauer, Charles M. Rath, F. M. Van Tuyl
Homer A. Scott, El Dorado, Kans.
Frank R. Clark, C. R. Thomas, Marvin Lee
Dana M. Secor, Tulsa, Okla.
Dollie Radler, L. B. Snider, Sidney Powers
Raymond Sidwell, Iowa City, Iowa
Allen C. Tester, A. C. Trowbridge, Gail F. Moulton
H. Jerome Wharton, Pittsburgh, Pa.
Ransom E. Somers, Roswell H. Johnson, L. G. Huntley

FOR TRANSFER TO ACTIVE MEMBERSHIP

G. Frank Aldrich, Fort Worth, Tex.
Claude F. Dally, Charles E. Yager, J. Elmer Thomas
William A. Barth, Shreveport, La.
J. Y. Snyder, W. E. Hopper, A. F. Crider
Clarence D. Beeth, Jr., Denver, Colo.
R. L. Heaton, W. F. Howell, A. E. Brainerd
William D. Blackburn, Fort Worth, Tex.
David Donoghue, Alexander Deussen, Wallace E. Pratt
Walter J. Boyle, Fort Worth, Tex.
Roy J. Metcalf, Ray V. Hennen, W. W. Patrick
Donald D. Braugh, Stillwater, Okla.
A. F. Truex, R. S. McFarland, James H. Gardner
Richard C. Harris, Los Angeles, Calif.
Desaix B. Myers, Earl B. Noble, C. R. McCollom
Robert L. Kidd, El Dorado, Kans.
John R. Reeves, J. M. Nisbet, W. L. Walker
Floyd G. Kerns, Enid, Okla.
Charles E. Yager, Ford Bradish, Ben C. Belt
Philip B. King, New Haven, Conn.
Charles Schuchert, Walter R. Berger, Sidney Powers
Roy Lebkicher, Denver, Colo.
Henry J. Hawley, S. H. Gester, F. A. Davies
Otto E. Nordman, Tulsa, Okla.
W. B. Wilson, A. I. Levorsen, George C. Matson
Richard B. Rutledge, Wichita, Kans.
Arthur E. Stander, L. W. Kesler, Roy H. Hall
Gene R. Smith, Dallas, Tex.
Frederic H. Lahee, W. A. Reiter, Angus McLeod
Alfred K. Tyson, San Antonio, Tex.
N. L. Thomas, L. T. Barrow, Charles H. Row

Charles D. Vertrees, San Angelo, Tex.
Hal P. Bybee, J. W. Beede, D. D. Christner
Hugh B. Webster, Oakland, Calif.
Henry J. Hawley, E. J. Young, Reg. C. Stoner
William G. Wender, Cisco, Tex.
Sidney Powers, H. G. Officer, John M. Lovejoy
Stanley B. White, Tulsa, Okla.
Thomas W. Leach, Ray V. Hennen, L. L. Foley
Albert G. Wolf, Houston, Tex.
George M. Bevier, Donald C. Barton, R. F. Baker

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
MEMBERSHIP LIST

March 1, 1928

HONORARY MEMBERS

The executive committee may from time to time elect as honorary members persons who have contributed distinguished service to the cause of petroleum geology. Honorary members shall not be required to pay dues, nor shall they be allowed to vote.—*Sec. 7, Article III, of the Constitution.*

Decker, Charles E., 508 Chautauqua Ave., Norman, Okla.
Hill, Robert T., Hotel Commodore, Los Angeles, Calif.
Orcutt, W. W., Union Oil Company Bldg., Los Angeles, Calif.
Smith, George Otis, Director, U. S. Geological Survey, Washington, D. C.
Udden, Johan August, Bureau of Economic Geology, University Station, Austin, Tex.
White, David, U. S. Geological Survey, Washington, D. C.

ACTIVE MEMBERS

Any person actively engaged in the work of petroleum geology or in research pertaining to petroleum geology or technology is eligible to active membership in the American Association of Petroleum Geologists, provided he is a graduate of an institution of collegiate standing, in which institution he has done his major work in geology, and in addition has had the equivalent of three years' field experience in petroleum geology; and provided further that in case of an applicant for membership who has not had the required collegiate or university training, but whose standing in the profession is well recognized, he shall be admitted to membership when his application shall have been favorably and unanimously acted upon by the executive committee; and provided further that these requirements shall not be construed to exclude instructors and professors in recognized institutions of learning whose work is of such a character as in the opinion of the executive committee shall qualify them for membership.—*Sec. 1, Article III, of the Constitution.*

Abrahamson, Hjalmar, 1002 Patterson Bldg., Denver, Colo.
Abruns, Harry W., Apartado 125, East Coast Oil Co., Tampico, Mexico.
Absher, William F., Empire Gas and Fuel Co., Geological Dept., Bartlesville, Okla.
Adams, Frank C., The Texas Company, Houston, Tex.
Adams, George I., University of Alabama, Tuscaloosa, Ala.
Adams, H. H., 415 W. T. Waggoner Bldg., Fort Worth, Tex.
Adams, William C., Box 2203, Tulsa, Okla.
Adkins, W. S., Bureau of Economic Geology, University of Texas, Austin, Tex.
Aguerrevere, Pedro I., Attn. Mrs. C. D. Wetmore, Librarian, H. L. Doherty & Co., 60 Wall St., New York, N. Y.
Aid, Kenneth, Pure Oil Co., Geological Department, Mexia, Tex.

Ainsworth, William L., 301 N. Yale St., Wichita, Kan.
Albertson, Maurice M., 449 Laurel St., St. Louis, Mo.
Alden, John M., U. S. Geological Survey, Box CC, Taft, Calif.
Allan, Thomas H., Box 362, Russell, Kan.
Allen, Bryant, Box 494, Eagle Pass, Tex.
Allen, E. G., Roxana Petroleum Corp., Athletic Club Bldg., Dallas, Tex.
Allen, Walter J., Box 2203, Tulsa, Okla.
Ambrose, A. W., Empire Gas and Fuel Co., Bartlesville, Okla.
Ames, Edward W., Box 818, Cisco, Tex.
Ames, E. R., 3210 Harrisburg Blvd., Houston, Tex.
Anderson, Amil A., 721-722 Union National Bank Bldg., Wichita, Kan.
Anderson, Carl B., 941 Kennedy Bldg., Tulsa, Okla.
Anderson, Frank M., 58 Hillcrest Road, Berkeley, Calif.
Anderson, G. E., 411 E. Keith, Norman, Okla.
Anderson, J. G., Jr., Lumbermen's Club, Houston, Tex.
Anderson, Robert V. V., Menlo Park, Calif.
Andreen, Harry M., Box 2045, Tulsa, Okla.
Andrews, Sylvan H., Box 471, Okmulgee, Okla.
Applin, Paul L., 1806 F. & M. Bank Bldg., Fort Worth, Tex.
Armstrong, Harold K., Oildale, Calif.
Armstrong, J. M., Prairie Oil & Gas Co., Eastland, Tex.
Arnett, Clarence L., 301 S. Eighth St., Ponca City, Okla.
Arnold, Emmett L., 538 Mayo Bldg., Tulsa, Okla.
Arnold, Ralph, 639 S. Spring St., Los Angeles, Calif.
Aronson, Sam M., Box 817, San Angelo, Tex.
Artman, George W., 515 W. Cleveland, Ponca City, Okla.
Ashley, George H., State Capitol, Harrisburg, Pa.
Athy, Lawrence F., 302 N. Fourth St., Ponca City, Okla.
Augur, Irving V., 410 Roosevelt Bldg., 727 W. Seventh St., Los Angeles, Calif.
Aurand, Harry A., 1350 Bellaire St., Denver, Colo.
Aurin, Fritz L., Marland Refining Co., Ponca City, Okla.

Bagg, Rufus M., 16 Brokaw Place, Appleton, Wis.
Bailey, Thomas L., Box 713, Ventura, Calif.
Bain, H. Foster, 29 W. Thirty-ninth St., New York, N. Y.
Baird, Chester A., Apartado 234, Venezuelan Gulf Oil Co., Maracaibo, Venezuela, S. A.
Baker, Charles Laurence, 529 Commercial Bank Bldg., Houston, Tex.
Baker, Norval E., Room 1567, 26 Broadway, New York, N. Y.
Baker, Raymond F., The Texas Co., Geol. Dept., Drawer F, Houston, Tex.
Baker, William A., Jr., Apartado 657, Tampico, Mexico.
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Memorial

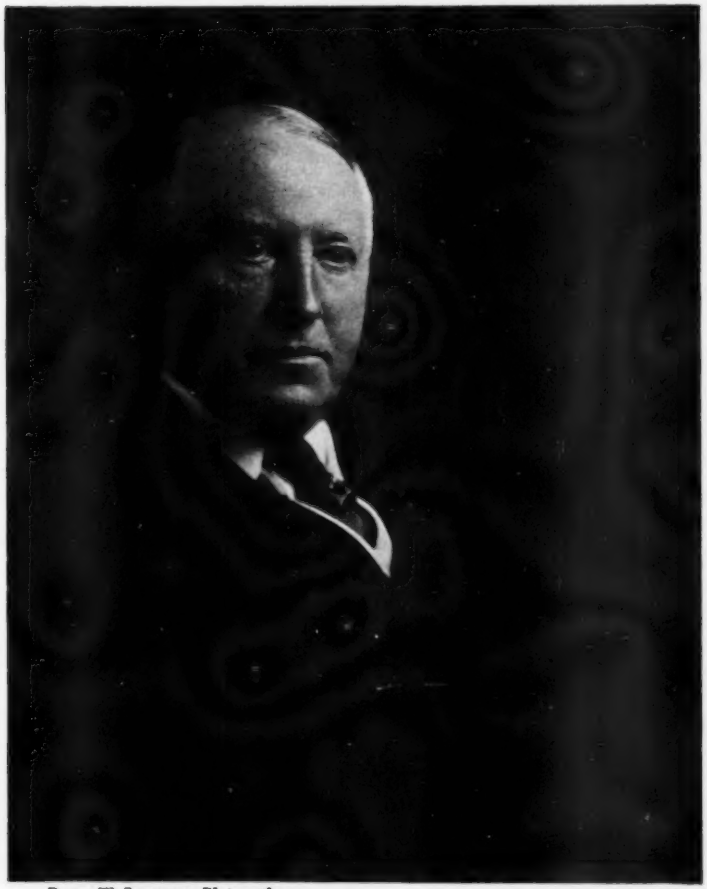
ISRAEL CHARLES WHITE

Dr. I. C. White, state geologist of West Virginia for the last thirty years, died on November 25, 1927, at Johns Hopkins Hospital, Baltimore, Maryland, aged 79. Three days previous to his death, an apparently successful operation had been performed and he seemed to be recovering from it but an attack of cerebral hemorrhage suddenly developed that proved almost instantly fatal. His interment took place in Morgantown, West Virginia. His sudden death was a shock to the scientific world and to his own community and commonwealth. He was widely acclaimed as "West Virginia's most distinguished citizen" by the press of the state, a distinction that had been achieved, not from any political activity, but from his great work as a scientist and his active participation in civic affairs without compensation. Although state geologist of West Virginia since the year 1897, he drew pay from the State only for the first two years, the last 28 years of this service being a "labor of love" for West Virginia.

Israel Charles White was born on a farm near St. Cloud in western Monongalia County, West Virginia, on November 1, 1848. On his father's side he was of English extraction, being a descendant of Stephen White who came over from England and settled near Baltimore in 1659. His maternal ancestors were Holland Dutch. His father, Michael White, was a very remarkable man and leader in the farming community in which Dr. White grew from infancy to boyhood, possessing great physical strength and a high degree of intelligence that made him the leader of the White clan of nine brothers. This was specially true when these all followed his (Michael's) lead in voting against secession when the question came up whether West Virginia should remain in the Union during the early days of the Civil War period. Both Michael White and Dr. White's mother (Mary Ann Russell) were intensely religious and members of the Methodist Episcopal church. Frequently the children, including Dr. White, were left at home to keep house while their parents attended camp meetings in distant communities. It was under such an environment as this that Dr. White spent his boyhood.

In the "fifties" of the 19th century, the educational facilities in West Virginia were meager, to the extent that Dr. White's early education was obtained largely at short sessions of school supported by private subscription when teachers could be obtained. At about the age of 20 he entered the West Virginia University at Morgantown with the idea of becoming a physician and surgeon. Shortly after his entrance in the university he assisted a local physician in performing an autopsy on a man in a mountaineer home near Morgantown, where the only tool available for the purpose was a hand-saw. The physician was an elderly man and the burden of the task fell on Dr. White and this experience so disgusted him with the medical profession that he then

and there decided to fit himself for some other branch of scientific endeavor. He graduated with highest honors from the West Virginia University in 1872, getting the degree of A. B., and three years later the degree of A. M., and in 1922 the degree of LL. D., all from the same institution. On the date of his death he was the oldest living graduate of West Virginia University. In 1880 the University of Arkansas awarded him the degree of Ph. D., and in 1922 the University of Pittsburgh, the degree of D. Sc.



RALPH W. JOHNSTON, *Photographer*

ISRAEL CHARLES WHITE, A.B., A.M., LL.D., Ph.D., D.Sc.

While in West Virginia University Dr. White studied geology under the late Dr. John J. Stevenson, one of the most eminent geologists in America and one who, after leaving West Virginia University, became professor of geology at the University of New York with which he was actively connected for more than 30 years. It was the talented teaching of Dr. Stevenson that created the desire in Dr. White to change from the profession first contemplated to that of a geologist, and further to equip himself for the profession he took a post-graduate course in geology at Columbia University, New York City, in 1875-76.

His first practical work in geology began in 1875 when he was appointed field aid to Dr. Stevenson, on the Second Geological Survey of Pennsylvania. Here he made rapid progress and was made full assistant geologist on the same survey in 1876, which position he held until 1883. During this period he prepared eight volumes or reports on the geology of counties in northwestern and central Pennsylvania as listed on a subsequent page. Although he covered a large area there in a limited time, yet the data presented in these reports or volumes were collected and analyzed with the greatest care, and this, taken in conjunction with their essential pioneer character, has caused them to become invaluable for reference purposes.

He was professor of geology at West Virginia University from 1877 to 1892, devoting his summer vacation periods to active work in the field on his Pennsylvania survey engagements, and writing up his reports largely at night during the winter months while teaching at the University in the daytime. At the University his teaching was marked by its practical character, and geology under him became a live study to the pupil. Even at that early date he often took his classes on wide excursions in the field through West Virginia and the adjoining states, sometimes absenting students from their other class work for almost a month.

From 1884 to 1888 he was assistant geologist on the staff of the United States Geological Survey. During this period he accumulated the data in the field and wrote *Bulletin 65* (U. S. Geological Survey), entitled "Stratigraphy of the Appalachian Coal Field," dealing mainly with the coal fields of Pennsylvania and West Virginia and laying the foundation for all subsequent geological work in those two states.

In 1882 he first promulgated what is known as the *anticlinal theory of oil and gas accumulation* and demonstrated the important part played by gravity in conjunction with anticlinal and domal types of geologic structure in the segregation of oil and gas into commercial pools. Previous to this time half-formed ideas existed in the minds of a few men but no authoritative discussion of these ideas had been made. His theory was finally published in "Science" under date of June 26, 1885. His advancement of this theory, as a scientific fact, brought on a prolonged discussion and criticism on the part of other geologists. He not only maintained his side of the controversy but by a close study and application of the theory to the potential oil and gas fields in wildcat areas of West Virginia and Pennsylvania, was enabled to make investments in oil and gas leaseholds and royalties which resulted so successfully that they not only proved his anticlinal theory but gained him a comfortable fortune, thus enabling him to indulge to a much greater degree in scientific pursuits.

In fact, his business and professional work increased to the extent that he was compelled to give up his professorship in geology at West Virginia University in 1892.

In signal honor of Dr. White's pioneer work in connection with the anticlinal theory, Mr. E. L. Doheny of California, about 1920, named a 12,000-ton oil tank ship for Dr. White. The ship was launched by the Sun Ship Building Company at Philadelphia and was christened "I. C. White" by one of Dr. White's granddaughters.

In 1897 the Legislature of West Virginia established the West Virginia Geologic Survey, Dr. White being absent from the country at the time as a delegate from the Geological Society of America to the meeting of the International Geologic Congress at St. Petersburg, Russia. Without waiting to consult him on his return, the State Geologic Survey Commission immediately appointed Dr. White as state geologist, which position he held until his death. While state geologist he supervised the preparation of a complete set of topographic maps of West Virginia on a scale of approximately one mile to the inch. He also supervised the preparation of, and edited, thirty-four geologic reports or volumes for the state, of which he himself was author of five, two of these being general reports on oil and gas in the state as a whole and three on coal in the state as a whole. At the time of his death two other reports of his assistants were almost off the press and two more were in active preparation. While all detailed county reports on West Virginia were prepared by assistant geologists on his staff, these were not only given constant attention by Dr. White but valuable suggestions were offered by him during their preparation. It was long an ambition of Dr. White to bring about the preparation, by the State Geological Survey, under his supervision, of a complete set of detailed geologic reports covering every county in West Virginia. This result was almost attained, since, at his death, only one county, Greenbrier, remained unstudied in detail.

In 1904 Dr. White received the highest recommendation to the Brazilian Government authorities of anyone in Europe or America as being peculiarly well fitted to make a report that might interest foreign capital in the development of the coal fields in the four southern states of Brazil, South America. For this purpose the position of chief of the Brazilian Coal Commission was offered in 1904 and accepted by Dr. White and held by him until 1906. He made two trips to southern Brazil, one in 1904 and the other in 1905, spending several months in the field on each trip, largely in wild and almost inaccessible regions on account of hostile Indians, as a rule with a guard of 20 to 25 Brazilian soldiers accompanying him. His purpose was to ascertain the extent and character of the coal beds and the quality of the coal, many tons of which were shipped to Germany and the United States for testing the best methods of washing and treating for fuel purposes. His final report in a single volume, printed page by page in both English and Portuguese, was published in 1908.

In 1908 Dr. White was chosen by Theodore Roosevelt to make the address on mineral fuels at the first White House Conference of Governors of the several states to discuss plans for the conservation of our natural resources. His address on "The Waste of Our Fuel Resources" at this conference was highly praised by the press of the country, and well-known author-

ities pronounced two or three paragraphs of the address as a classic ranking with other great inspirations in English literature.

Dr. White was a charter member of the Geological Society of America, serving as its treasurer from 1892 to 1907, and as its president in 1920. He was also a charter member of the American Association of Petroleum Geologists and served as its president for one year (1919-20). Other memberships in scientific organizations were in the American Association for the Advancement of Science, serving as the vice-president of Section E (Geology) in 1906-07; the Association of American State Geologists, being its president in 1913-15; the American Philosophical Society; the American Association of Mining and Metallurgical Engineers; the American Mining Congress; Geological Society of Washington, D. C.; Washington Academy of Science; and Natural Gas Association of America. In almost all of these organizations he took an active part. He was a delegate from the Geological Society of America to the International Geologic Congress in St. Petersburg, Russia, in 1897, and again at Paris, France, in 1900.

Socially, Dr. White belonged to the Cosmos Club of Washington, D. C.; the Rocky Mountain Club and the Old Colony Club, both of New York City; the Morgantown Country Club, being its president at the time of his death; and the Kiwanis Club of Morgantown.

In spite of his active scientific life, Dr. White found considerable time to devote to business activities. He was an anomaly in this respect as compared with the average scientific man, in that he possessed a shrewd business mind and his counsel and judgment were highly respected by the leading business men and organizations of his home town, county and state. In Morgantown, West Virginia, he was president of the Union Utility Company, 1902-03; director of the Farmers & Merchants Bank, 1895-1922; director of the Bank of the Monongalia Valley, 1922-26; president of the Morgantown Brick Company for many years. He also took an active part in the management of several real estate companies and oil and gas royalty-holding corporations.

Dr. White found much time to devote to civic affairs and his participation in this line of work was much sought for the reason that he was known to carry through to a successful conclusion almost any line of endeavor with which he became associated in an active way. In this connection he served as vice-president for West Virginia of the International League for Highway Improvement; as president of the West Virginia Board of Trade; as president of the Morgantown Board of Trade; as member of the National Advisory Board appointed by President Roosevelt in 1906; as member of the Federal Trade Commission and Chamber of Commerce of the United States of America; as trustee of Kiwanis International, 1923-25; as treasurer of the West Virginia University Stadium Corporation; and was actively concerned with the Monongalia County Hospital and the Monongalia Tuberculosis Sanitarium. To some of these enterprises he not only gave a considerable portion of his time, but large contributions of money. In fact, he was always found supporting any progressive movement of a civic nature that tended to bring about better living conditions regardless of how it might affect him from a tax standpoint. He was a republican in politics, but a more or less independent voter. His

only political activity was as a delegate in 1892 to the Minneapolis convention at the second nomination of President Harrison.

One of Dr. White's outstanding donations was the giving of 1,900 acres of Sewickley Coal, a thick and valuable deposit of fuel in Marion County, West Virginia, to the city of Morgantown and West Virginia University jointly. The deeds provided that the revenue to the city derived from the development of the coal tract was to be used for hospital and park purposes, while the University's revenue was for the promotion of the geological department and the furtherance of geologic study. He also gave to the city Whitmoor Park in East Morgantown.

Dr. White was married three times, first to Emily McLane Shay of Morgantown, West Virginia, on July 27, 1872, to which union one daughter, Emily McLane Mills Fisher (deceased), was born; second to Mary Moorhead of New Castle, Pa., on Dec. 4, 1878, by whom he had five children, namely, Nell Moorhead, wife of C. W. Maxwell of Elkins, West Va., Fanny Russell, wife of H. Platt Brightwell of Charleston, West Va., Edith Edna Miller, wife of K. L. Kithil, Denver, Colo., Charles Stevenson, purchasing agent, N. Y. Central Railroad Lines, New York, and Mary Gertrude, wife of E. R. Wise; and third to Mrs. Julia Posten Wildman of Morgantown, West Virginia, who survives him. Dr. White is also survived by an elder brother, ex-state senator H. S. White of Matewan, West Virginia, who, at the age of 87 years, is still active in business and at the present time is a special representative of the State Road Commission.

In his domestic relations, Dr. White was always a cultured gentleman and as one has aptly said "of quiet manner and unruffled mien." He was always helpful with advice not only to young college students, but to young men and women in other walks of life. He was always entirely devoted to his family and took great pride in his many grandchildren, so that to his family and the scientific staff that has been associated with him, his loss has been a great shock, as it has been to the scientific world.

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1901 to 1927 1 Bulletin; 4 General Volumes; 24 County Geological Reports (published), 2 County Reports (in press), and 2 County Reports (in preparation). All prepared by members of West Virginia Geological Survey staff under scientific and editorial supervision of Dr. I. C. White. (These are in addition to the 5 volumes previously listed as prepared by himself.)

RAY V. HENNEN

TULSA, OKLAHOMA
January, 1928

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

W. A. J. M. VAN DER GRACHT, of the Marland Oil Company, sailed for Holland with Mrs. van der Gracht last February.

RAYMOND G. TRAVIS, of the Cia Minera Chocó Pacifico of Andagoya, Colombia, returned to the United States last January with the expectation of visiting France in March.

WALLACE LEE returned from Central America last September and is now organizing a geological department for the Denver Producing and Refining Company at Okmulgee, Oklahoma.

IONEL I. GARDESCU has returned to Berkeley, California, from Venezuela, where he was engaged in reconnaissance for the California Petroleum Corporation. He is now studying for his doctorate in petroleum engineering.

HARRY A. CAMPBELL is a member of the firm of Campbell, Collard & Barrett, Atlas Life Building, Tulsa, Oklahoma. The business is general tax consultation and practice.

A. W. WEEKS is district geologist for the Roxana Petroleum Corporation at San Antonio, Texas. Before joining the geological department of the Roxana about three years ago, he was geologist for the Midwest Refining Company in the Texas Panhandle and Rocky Mountain regions.

FRANK A. MORGAN, for the past seven years associated with E. A. Starke, chemist and consulting petroleum engineer and geologist of Los Angeles and San Francisco, has opened independent offices in the new Security Title Insurance Building, corner 6th Street and Grand Avenue, Los Angeles.

F. P. SHAYES, geologist for the Houston Oil Company, is now at Beeville, Texas, and J. BOYD BEST has been transferred from Laredo, succeeding Mr. Shayes at Houston.

NOYES B. LIVINGSTONE, geologist with J. ELMER THOMAS and ROY A. REYNOLDS of Fort Worth, Texas, has been attending the University of Chicago for the past few months.

VIRGIL B. COLE is employed by the Gypsy Oil Company at Wichita, Kansas.

ROY A. WILSON, chief geologist for the California Petroleum Corporation of Venezuela, was in the United States last January and returned to Venezuela in February accompanied by a party of field geologists for exploratory work. The company's headquarters is at Caracas.

GEORGE SEVERSON, formerly with the Atlantic Refining Company, is now with the California Petroleum Corporation of Venezuela with headquarters at Caracas.

H. B. THOMSON, recently superintendent of field operations with the Gilmore Oil Company with headquarters in Los Angeles, is now with the Indian Territory Illuminating Oil Company as petroleum engineer in charge of gas-lift operations in the Seminole division of Oklahoma.

HUGH D. CRIDER, of the Dixie Oil Company and a nephew of A. F. CRIDER, chief geologist of the company at Shreveport, Louisiana, is credited with locating the first oil well in Muskegon County, Michigan.

DEAN E. WINCHESTER, consulting geologist, 230 Steel Building, Denver, Colorado, is the author of a report on "The Oil Possibilities of the Oil Shales of the United States" which was printed as Appendix 1 to the Second Report of the Federal Oil Conservation Board, and reprinted in the *Oil Weekly* for February 3, 1928, page 44.

E. F. MILLER, for the past four years associated with the Marland Oil Company of Colorado with headquarters at Denver, is now in charge of geological work for the Reiter-Foster Oil Corporation, 915 Mid-Continent Building, Tulsa, Oklahoma.

FREDERICK G. CLAPP, consulting geologist of 50 Church Street, New York City, returned to Teheran, Persia, last January, after a reconnaissance through the northern provinces of Mazandaran, Asterabad, Semnan, and Gilan.

The WEST TEXAS GEOLOGICAL SOCIETY held its regular meeting in the Petroleum Club Room of the St. Angelus Hotel, San Angelo, at 7:30 P. M., February 4, 1928. F. B. PLUMMER presented a paper on "The Geological Factors which Control the Location of Pools in Central and West Texas." The society holds an informal luncheon for members and visitors at 12:15 P. M., on the third Saturday of each month, at the St. Angelus Hotel.

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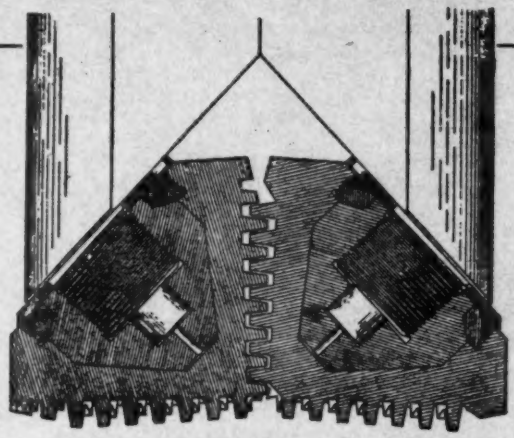

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